# Inhibitory control, reinforcement and personality: Implications for gambling behaviour.

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# INHIBITORY CONTROL, REINFORCEMENT AND PERSONALITY: IMPLICATIONS FOR GAMBLING BEHAVIOUR

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Thesis submitted to the University of Wales in fulfilment of the requirements for the Degree of Doctor of Philosophy

September 2009

# Abstract

This thesis presents studies investigating interrelated aspects of inhibitory control, reinforcement, personality and gambling behaviour. Inhibitory control was measured on various different behavioural tasks including stop-signal tasks with different reinforcement contingencies, computerised gambling tasks (i.e., card perseveration (CP) tasks and slot machine simulations), and the Q-task. Associations between self-reported sensitivity to reward/punishment (i.e., personality) and inhibition on these tasks were investigated since it was anticipated that performance might be related to, and, therefore, explained in terms of, constructs of the Reinforcement Sensitivity Theory (RST) (and related theories) of personality. Finally, inhibitory control and personality in pathological gamblers was investigated due to the potential of RST, and related theories, in throwing new light upon the disinhibited behaviour characterised by pathological gambling (PG).

Results demonstrated that inhibitory control on the stop-signal task can be modified using different response contingencies. Evidence was produced to suggest that self-reported personality was associated with performance on each of the behavioural tasks employed. However, evidence was also produced indicating the importance of assessing reinforcement expectancies in relation to behavioural tasks in order to produce theoretically consistent relationships between presumed appetitive/aversive situations and self-reported sensitivity to reward/punishment. Results indicated that although pathological gamblers (vs. non-problem gambling controls) did not demonstrate impaired inhibitory control on the stop-signal task or less inhibition on the Q-task, their response inhibition was differentially effected by the presence of different reinforcement contingencies on the stop-signal task; and, in addition, the PG group demonstrated greater response perseveration on the CP task and across slot machine simulations.

Other findings include pathological gamblers' (as well as controls') response perseveration shown to be reduced on the CP task by imposing a 5-s forced pause following response feedback – a finding discussed as having potentially valuable implications for informing practice in the treatment of PG – and the revelation that PG participants scored higher (vs. controls) on self-report measures of Gray's BIS, BAS and FFFS, indicating that pathological gamblers were hyper-sensitive to reward as well as to punishment – a finding discussed within the context of Corr's (2009) and McNaughton and Corr's (2009) recent alternative explanation for the development and maintenance of PG based on the concept of 'relief of non-punishment'.

# Declaration and Statements

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed.......................................................... (candidate)
Date.....29/09/09...................................

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Where information has been derived from other sources, this has been indicated through explicit references.

Signed.......................................................... (candidate)
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STATEMENT 2

I hereby give my consent for my thesis, if accepted, to be available for photocopying and for inter-library loan, and for the title and abstract to be made available to outside organisations.

Signed.......................................................... (candidate)
Date.....29/09/09...................................

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# Acknowledgements

A great many individuals assisted both directly and indirectly in the work involved in this thesis, and a note of acknowledgement here is but a small token of my indebtedness to them.

I am very grateful to Professor Philip J. Corr, my supervisor, who read each chapter tirelessly and most carefully, offered constructive criticism throughout as to quality and quantity, and who provided me with the intellectual stimulation, support, and confidence to complete this thesis. Thank you Philip.

I am also grateful to Dr. Søren Bo Andersen and Dr. Andrew Cooper, both of whom acted as my secondary supervisor for brief periods, for the encouragement and support they provided in the early stages of this research.

Many thanks to Celtic Bookmakers, for allowing me to advertise and recruit for participants on their premises, and thanks to all of the participants, who so willingly took part in the research.

Thanks to all of my close friends, for keeping things in perspective and for being there when I was in need of a laugh.

To my parents and my sister, Steph; thank you for your support and belief throughout. It is the same whatever I choose to do – you are always there for me and words cannot express my appreciation.

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# Chapter 1

# Introduction

Consider the following: You are driving along a country lane about to overtake a tractor in front of you when a car approaching from the opposite direction appears in the distance. After briefly considering the length of the tractor and the speed of the approaching car, you decide to stay behind the tractor. This example illustrates the importance of inhibitory control as a self-regulating function. It allows the individual to react efficiently to sudden changes in the environment (de Jong, Coles, Gratton, & Logan, 1990) and may be defined simply: 'It refers to the ability of the organism to withhold a planned response; to interrupt a response that has been started; to protect an ongoing activity from interfering activities; and to delay a response' (Rubia, Oosterlaan, Sergeant, Brandeis, & Leeuwen, 1998, p. 25).

Stopping is a useful act of control and can be studied empirically using a simple laboratory analogue called the 'stop-signal paradigm' (Logan, 1994; Logan & Cowan, 1984). Many different aspects of inhibitory control have been investigated under a variety of experimental conditions using this paradigm. However, to date, limited research has been directed at potential methods for modifying inhibitory control. Investigation of effective methods for modifying inhibitory control on behavioural tasks such as the stop-signal paradigm could provide valuable information on how to moderate and explain inhibitory control in situations (e.g., gambling) where disinhibitory behaviour leads to deleterious outcomes.

The aim of this thesis, therefore, was to investigate the possibility that inhibitory control can be modified using different specific motivational stimuli (i.e., reinforcement). Personality was also examined in relation to inhibitory control, since it was anticipated that individual differences in inhibitory control and any observed modifications in this important self-regulating function might be associated with, and, therefore, explained in terms of, individual differences in reinforcement sensitivity. Additionally, since the revelation of effective methods for modifying inhibitory control could provide valuable information on how to moderate and explain maladaptive disinhibitory behaviour characterised in certain clinical groups (e.g., pathological gamblers, psychopaths, children with attention deficit/hyperactivity disorder), inhibitory control and personality in pathological gamblers was also investigated. Gambling provides an appropriate context in which to test constructs of the Reinforcement Sensitivity Theory (RST) of personality. RST, and related theories, may throw new light upon problematic gambling behaviour – it may also help to explain why the majority of gamblers do not develop problematic behaviour.

This introduction first describes the stop-signal paradigm, presents previous studies using the 'standard' version of this task (no specific motivational stimuli), and presents and discusses the limited number of previous studies that have attempted to modify inhibitory control using stop-signal tasks with different response contingencies. Next, personality psychology is introduced, focusing on arousal theory and RST and how they might predict inhibitory control, and previous studies relating personality to inhibitory control on standard as well as modified versions of the stop-signal task are presented and discussed. Gambling behaviour is then described and literature demonstrating the association of the pathological form of this behaviour with personality factors such as impulsivity is presented, leading to a discussion of the ways in which RST could provide a promising theoretical framework for understanding the motivational dynamics underlying pathological gambling (PG).

Following on from the discussion of RST and PG, the growing literature demonstrating an association between impaired inhibitory control and PG is discussed, none of which has included evidence obtained using the stop-signal paradigm since, to my knowledge, no previous research has examined inhibitory control in pathological gamblers using this paradigm. Reasons are then put forward to validate the suggestion that utilising the paradigm for this purpose has the potential to advance knowledge and understanding of pathological gamblers' inhibitory control, and then a number of other behavioural tasks, some designed to be ecologically valid gambling tasks (e.g., computerised slot machine simulations), are presented and described, along with previous studies demonstrating their empirical application, as potentially useful tools to be administered alongside the stop-signal paradigm. Finally, the aims and hypotheses of the present thesis are presented.

### 1.1 The stop-signal paradigm

Numerous tasks have been developed in the context of experimental psychology for the assessment of inhibitory control and deficiencies in the response inhibition process. Of these, the stop-signal paradigm task is arguably one of the most valid and reliable (Kindlon, Mezzacappa, & Earls, 1995; Logan, 1994); based on a well-established theory of response inhibition, known as the race model (see Logan, 1994; Logan & Cowan, 1984). The paradigm is unique due to its direct assessment of the ability to inhibit a pre-potent behavioural response. It differs from 'reactive' inhibition models, such as inhibition of return (Posner & Cohen, 1984), negative priming (Tipper, 1985), and Stroop interference (MacLeod, 1991), that measure inhibition of an action that results from interference owing to some other competing behavioural response. Compared to these models, the stop-signal paradigm is assumed to provide a more direct measure of inhibitory control.

Stopping is a case of internal intervention and the paradigm makes it possible experimentally to characterise the nature of this internal inhibitory response through indirect measurement of the stopping process. Individuals are engaged in a primary task, typically a visual choice reaction time task involving discrimination between different letters or images, and occasionally and unpredictably, they are presented with a signal that prompts them to stop their response to the primary task. The stop-signal can be visual or auditory and the main data of the paradigm is whether or not individuals inhibit their response to the primary task when presented with the stop-signal, or how much 'notice' they need in order to be able to stop their response. Analysis of stopping performance has traditionally been based upon the race model which, in contrast to other measures of response inhibition, affords measurement of the underlying inhibitory control process.

According to the race model, response inhibition depends on the outcome of a 'race' between two independent processes: the go process (triggered by the primary task stimulus and involving detection, response choice and preparation of response) and the stopping process (triggered by the stop-signal and involving detection of the signal and the inhibition of response; Logan, 1994; Logan & Cowan, 1984). The process that runs to completion first wins the race and determines response behaviour. If the 'go' process runs to completion first, it wins the race and a response occurs; but if the 'stopping' process runs to completion first, it wins the race and a response is inhibited. Varying the timing of the stop-signal relative to the respond signal (i.e., the stop-signal delay) biases the race in favour of one process or the other; this manipulates the probability of successful stopping. Stopping becomes increasingly more difficult the longer the stop-signal delay (i.e., the later the stop-signal is presented in relation to the respond signal; e.g., Lappin & Eriksen, 1966; Logan, 1994; Logan & Cowan, 1984).

The latency of the inhibitory process is internal and unobservable and, therefore, unlike go-signal reaction time, stop-signal reaction time (SSRT) cannot be measured directly. The outcome of the presentation of the stop-signal is either successful inhibition or failure to inhibit. If failure to inhibit is the outcome, SSRT must have been slower than the observable latency of the go-signal response. However, it is not clear how much slower the SSRT was as it has no observable latency. If successful inhibition is the outcome, SSRT must have been faster than the go-signal reaction time, but no observable response with a measurable latency is provided by either the go process or the stop process so SSRT remains unobservable. This means that 'something beyond direct observation is required' (Logan, Schachar, & Tannock, 1997, p.61). The race model of the stop-signal paradigm provides a method for estimating SSRT using the distribution of go-signal reaction times and the probability of responding given a stop-signal delay (Logan & Cowan, 1984). This method assumes that SSRT is constant and is described in detail in chapter 2, section 2.1.1.5.1.

Choosing and setting stop-signal delays is an important matter in the design of any stop-signal task. At some delays, participants will inhibit responses every time while at other delays they will respond every time. It is imperative that the intermediate delays, at which the probability of responding is between 0 and 1, are found in order for response inhibition to be accurately assessed. To achieve this, Logan (1995) suggested that at least three or four delays should be employed. If only one delay is used, participants will prolong their go-signal reaction times in order to maximise the probability of successful inhibition (Lappin & Eriksen, 1966; Logan, 1981). Prolongation can be minimised by presenting several early and late delays that break the contingency between variation in go-signal reaction time and probability of inhibition; some delays should be early enough that participants will be able to inhibit most of the time, and some should be late enough that participants will almost always respond when they occur (Logan, 1981). The implementation of numerous such delays should result in a negative slope function relating probability of inhibition to stop-signal delay (e.g., Fillmore & Rush, 2002; Fillmore, Rush, & Hays, 2002; Fillmore, Rush, Kelly, & Hays, 2001).

The presence of a negative slope function relating probability of inhibition to stop-signal delay not only provides verification of successful employment of intermediate delays at which the probability of responding is between 0 and 1 (see above), but also that participants understood task requirements and correctly followed instructions. It is possible for task performance to be affected by random response strategies and by inattention, owing to a lack of interest or motivation on the part of the participant (see Schachar, Tannock, Marriott, & Logan, 1995; Tannock, Schachar, & Logan, 1995). The slope function can be used to detect such response styles. Randomly inhibiting and executing responses on stop-trials would generate a flat slope function since such a response strategy would result in inhibitions being equally likely to occur at all delays. Obtaining a negative slope demonstrates that response inhibition was under some degree of stimulus control of the stop-signals on the task.

Logan (1995) suggested several methods for deciding upon stop-signal delays, ranging from choosing them arbitrarily and fixing them across all participants and all conditions to tracking several parameters of participants' performance (e.g., go-signal reaction time) and setting delays contingent on the values of those parameters. For the purpose of the studies in the present thesis, four fixed delays were used (50, 150, 250 and 350-ms) based on previous research demonstrating consistent negative slope functions relating probability of inhibition to stop-signal delay across different groups of participants and different conditions using these same four arbitrarily chosen delays; probability of inhibition was shown to decrease in an orderly, linear fashion as the delays increased from 50 to 350-ms (see Figure 1.1; Fillmore & Rush, 2002; Fillmore et al., 2001, 2002).

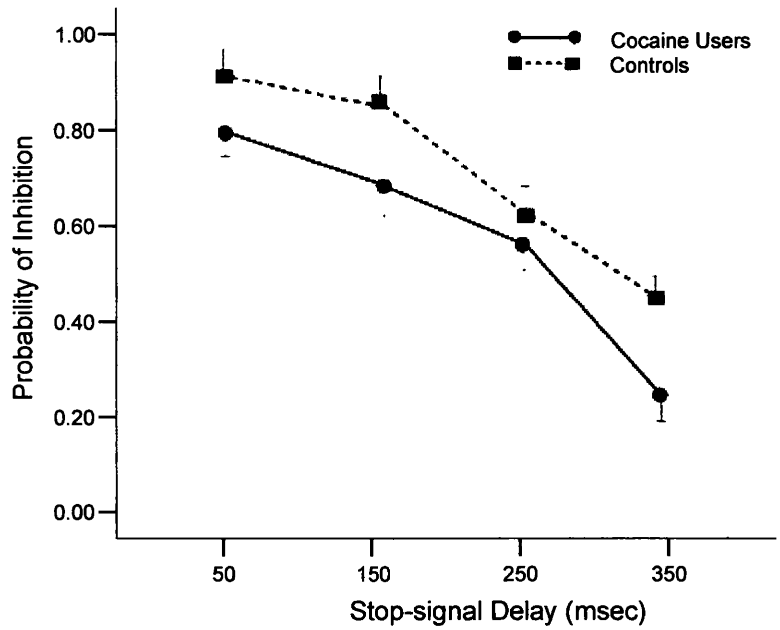


*Figure 1.1.* Mean probability of inhibiting a response (*P*-inhibition) to 12 stop-signals at each of four stop-signal delays (50, 150, 250, 350-ms) for cocaine users (n = 22) and controls (n = 22). Vertical capped lines indicate 1 SE of the mean. *Note.* Adapted from: "Impaired inhibitory control of behavior in chronic cocaine users," by M.T. Fillmore and C.R. Rush, 2002, *Drug and Alcohol Dependence, 66,* p. 270.

### *1.1.1 Previous research utilising the paradigm*

The stop-signal paradigm has been used for research into many different aspects of inhibitory control under a variety of experimental conditions. For example, it has been used to examine young adults when they try to interrupt over-learned responses, such as speaking (Ladefoged, Silverstein, & Papcun, 1973), incompatible responses (Logan, 1981), and continuous actions such as typing (Logan, 1982). It has been successfully applied to examining stopping in the elderly (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Williams, Ponesse, Schachar, Logan, & Tannock, 1999) and in children (Band, van der Molen, Overtoom, & Verbaten, 2000; Ridderinkhof, Band, & Logan, 1999; Schachar & Logan, 1990). Deficiencies in inhibitory control in clinical groups have been indicated, of which attention deficit/hyperactivity disorder (AD/HD) children seem to be the most widely researched (e.g., Jennings, van der Molen, Pelham, Brock, & Hoza, 1997; Oosterlaan & Sergeant, 1998; Overtoom et al., 2002; Schachar & Logan, 1990). Other studies have investigated the effects of alcohol (Mulvihill, Skilling, & Vogel-Sprott, 1997), cocaine (Fillmore & Rush, 2002; Fillmore et al., 2002) and methylphenidate (Tannock, Schachar, Carr, Chajczyk, & Logan, 1989). Inhibitory control as indexed by brain evoked potentials (de Jong, Coles, & Logan, 1995; de Jong, Coles, Logan, & Gratton, 1990; van Boxtel, van der Molen, Jennings, & Brunia, 2001), response force changes (van den Wildenberg, van Boxtel, & van der Molen, 2003), single-cell brain activity (Hanes et al., 1998), muscle activation (McGarry & Franks, 1997), and heart rate changes (Jennings, van der Molen, Brock, & Somsen, 1992), have also been assessed. Finally, it has not only been successfully applied to human subjects but also to monkeys (Hanes, Patterson, & Schall, 1998).

The stop-signal task used to investigate inhibitory control in the bulk of previous studies (including all of the studies mentioned above) had no specific motivational stimuli. Although it could be argued that the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), there is still a lack of any specific motivational stimuli on the standard task based on Logan's original. The introduction of specific motivational stimuli could potentially modify task performance.

#### *1.1.1.1 Stop-signal tasks with specific motivational stimuli*

Previous studies employing stop-signal tasks with specific motivational stimuli are very few to date. Oosterlaan and Sergeant (1997) examined whether AD/HD children's impaired inhibitory control reflects a motivation deficit. The authors tested four groups of children (14 AD/HD children, 14 disruptive children, 14 anxious children, and 21 normal controls) once on a task with reward contingencies and once on a task with response cost contingencies. In the reward condition, children earned credits for successful response inhibition (i.e., successfully stopping for stop-signals). In the response cost condition, children lost credits for failing to inhibit responses (i.e., failing to stop for stop-signals). The aim of Oosterlaan and Sergeant's study was to show that if a motivational deficit underlies weak inhibitory control in AD/HD children, then response contingencies in the stop-signal task should remedy this deficit. The authors concluded that their findings argue against a motivational explanation for the weak inhibitory control in AD/HD children since 'despite the presence of response contingencies, AD/HD children showed poor response inhibition compared with normal controls' (Oosterlaan & Sergeant, p. 161). However, as well as being limited by small sample sizes, this study did not allow Oosterlaan and Sergeant to determine the effects of rewarding and punishing contingencies as such, since they did not include a condition in which there were no contingencies. The authors, therefore, leave open the possibility that response contingencies affect inhibitory control on the stop-signal task relative to no contingencies.

Rodriguez-Fornells, Lorenzo-Seva, and Andres-Pueyo (2002) tested twenty male participants on two conditions. In the first condition participants performed a stop-signal task with no specific motivational stimuli (a standard task based on Logan's original), and in the second condition participants performed the same task in an approach-avoidance conflict situation. This approach-avoidance conflict situation was created by rewarding participant's speed of response to the go-signal and punishing their lack of inhibition to the stop-signal. Rodriguez-Fornells et al. found that inhibitory control was stronger (the proportion of successfully inhibited responses on stop-trials increased and SSRT was faster) in the second (approach-avoidance) condition than it was in the first, indicating a strengthened inhibitory control on the stop-signal task in the presence of specific rewarding/punishing stimuli compared to on the standard (no specific motivational stimuli) task.

However, Rodriguez-Fornells et al. (2002) reversed the assignment of responses to the two subsets of stimulus letters in the second condition compared to the first in an attempt to avoid practise effects. This may not have been an appropriate method to employ as it was likely to have unintentionally induced reversal learning (i.e., participants had to learn to avoid the effects of the learned response from the first condition in order to successfully perform the second) as well as controlling for practise effects as intended. This means that, in the second condition, participants first had to inhibit the learned response from the first condition and then respond in the new way, resulting in an unreliable comparison between the two tasks. The assignment of responses to the two subsets of stimulus letters could have been kept the same for both conditions in order to avoid this reversal learning effect. Practise effects across the two conditions could have been controlled for by counterbalancing the order of the two conditions and then investigating any order effects.

#### *1.1.1.2 Summary*

The vast majority of previous studies utilising the paradigm to investigate inhibitory control have focused explicitly on 'standard' versions of the task, with no specific motivational stimuli. Of the two previous attempts that have been made to design and implement tasks with specific rewarding and punishing contingencies, both have been limited in certain ways. However, despite their limitations, these studies have helped to open the door into a new and exciting area of research with the stop-signal task. The idea that performance on the task can be modified using rewarding/punishing stimuli could provide valuable information on how to moderate and explain inhibitory control in other situations (e.g., gambling behaviour). Any observed modifications in task performance could potentially be explained in terms of individual differences in reinforcement sensitivity (i.e., personality); which is the subject of the following section.

## 1.2 Personality

Personality as a human science has matured rapidly within the past twenty years or so resulting in a growing consensus about the findings and concepts that have stood the test of time. Consequently, as noted by Mischel, Shoda, and Smith (2004, p. 3) 'a unifying conception of personality and, more modestly, at least a broadly acceptable definition, is becoming possible'. Pervin (1996) provides a strong candidate for such a definition:

> Personality is the complex organization of cognitions, affects, and behaviors that gives direction and pattern (coherence) to the person's life. Like the body, personality consists of both structures and processes and reflects both nature (genes) and nurture (experience). In addition, personality includes the effects of the past, including memories of the past, as well as constructions of the present and future. (p. 414)

Consistent with that definition, views have been expanded to recognise that human tendencies are a crucial part of personality. According to Mischel (1980, p. 17) 'personality psychology must . . . study how people's [thoughts and actions] . . . interact with - and shape reciprocally - the conditions of their lives'. This view takes into account not only personal tendencies but also psychological processes (such as motivation, learning, and thinking) that interact with biological-genetic characteristics of the person. Personality is therefore a psychological concept but is also assumed to link with the physical, biological processes that influence the individual's distinctive patterns of adaptation throughout the life span.

### *1.2.1 Arousal theory and Reinforcement Sensitivity Theory*

Hans Eysenck is regarded as a pioneer in attempting to link psychological dispositions to their biological foundations. Eysenck's body of research and theories (Eysenck, 1990; Eysenck & Eysenck, 1985, 1995) focused on the characteristics of extraverts versus introverts. According to

Eysenck's (1967) arousal theory of Extraversion (E), extraverts are described as active, outgoing, and impulsive (E+), whereas introverts are characterised as the opposite: withdrawn, quiet, and anxious (E-). Eysenck proposed that introverts differ from extraverts due to variations in their physiological level of arousal (LOA) in the brain. Specifically, these differences were suggested to be influenced by the ascending reticular activation system (ARAS) of the brain; the system thought to regulate overall arousal in the cortex. According to this theory, compared with E+ individuals, E- individuals have lower response thresholds of their ARAS and, thus, higher cortical arousal. As a consequence of their lower response thresholds, in general, introverts (E-) are more cortically aroused and more arousable when exposed to sensory stimulation.

However, a protective mechanism, known as transmarginal inhibition (TMI), also has a moderating influence on the relationship between arousal-induction and actual arousal. TMI can sever the link between increasing stimuli intensity and behaviour at high intensity levels so that, when faced with low intensity stimulation (e.g., placebo or quiet), E- individuals should show greater arousal/arousability than E+ individuals, but when faced with high intensity stimulation (e.g., caffeine or noise), introverts (E-) should experience over-arousal which, through the moderating influence of TMI, can result in comparatively lower increments in arousal to that shown in extraverts (E+). Conversely, E+ individuals when faced with low intensity stimulation should be less aroused/arousable than E- individuals, but when faced with high intensity stimulation, they should show higher increments in arousal as compared to introverts (E-). Eysenck proposed that the second major dimension of personality is emotional stability or Neuroticism (N); related to activation of the limbic system (see Eysenck & Eysenck, 1985). This dimension describes at one end people who tend to be calm, stable, carefree, even-tempered, and reliable (N-). At the other extreme are people who are characterised by such terms as touchy, moody, anxious, and restless (N+).

Since stopping is 'an internally generated act of control . . . triggered by certain circumstances' (Logan, 1994, p. 190-191), it would be reasonable to expect carefree (N-) individuals to be less aware of changing circumstances and therefore less ready to stop an ongoing activity than anxious

(N+) individuals. Also, since the go-signal in the stop-signal paradigm may be interpreted 'as a reward and goal-directed cue' (Avila & Parcet, 2001, p. 983), it would be reasonable to expect active, impulsive (E+) individuals to be more motivated in approaching this stimulus (particularly if the potency of this rewarding stimulus were to be strengthened) than withdrawn, anxious (E-) individuals. In contrast, it would be reasonable to expect withdrawn, anxious (E-) individuals to be more motivated in inhibiting responses to punishing stop-signals (particularly if the potency of this punishing stimulus were to be strengthened) than impulsive (E+) individuals.

It was against the backdrop of Eysenck's arousal theory of Extraversion (Eysenck, 1967) that Reinforcement Sensitivity Theory (RST) developed. Jeffrey A. Gray, through his seminal work in the neuroscience of personality, was a key figure responsible for the rapid maturation of personality psychology and he, like Eysenck, emphasised the importance of biological/physiological foundations in personality theory: 'In the long run, any account of behaviour which does not agree with the knowledge of the neuro-endocrine systems...*must be wrong.*' (Gray, 1972a, p. 373). Gray's (1970, 1972b, 1981) proposals for an alternative psychophysiological theory of introversion-extraversion included rotating E and N (in factor space) by approximately 30° to form the more causally efficient axes of 'punishment sensitivity', reflecting Anxiety (Anx), and 'reward sensitivity', reflecting Impulsivity (Imp) (Figure 1.2; see Pickering, Corr, & Gray, 1999). RST gradually developed to identify three major systems of emotion: the Fight-Flight System (FFS), the Behavioural Approach System (BAS), and the Behavioural Inhibition System (BIS); that are proposed to be activated by specific classes of input stimuli, and are thought to vary in their sensitivity to these input stimuli across individuals (Gray, 1982, 1987).

According to Gray's (1982, 1987) 'standard' RST, the FFS was hypothesised to be activated by unconditioned aversive stimuli (i.e., innate pain), mediating the emotions rage and panic. In contrast, the BAS was hypothesised to be activated by conditioned appetitive stimuli (i.e., signals of both reward and the termination/omission of punishment), forming a positive feedback loop. The BIS was hypothesised to be activated by conditioned aversive stimuli (i.e., signals of both punishment and the termination/omission of reward) but also by innate fear stimuli (e.g., blood, snakes), extreme novelty, and high intensity stimuli. In terms of Eysenck's (1967) Extraversion scale, the BAS ranges from E+/N+ (Imp+) to E-/N- (Imp-; Imp+ is rotated 30° from E; Gray, 1970; Pickering et al., 1999; see Figure 1.2).

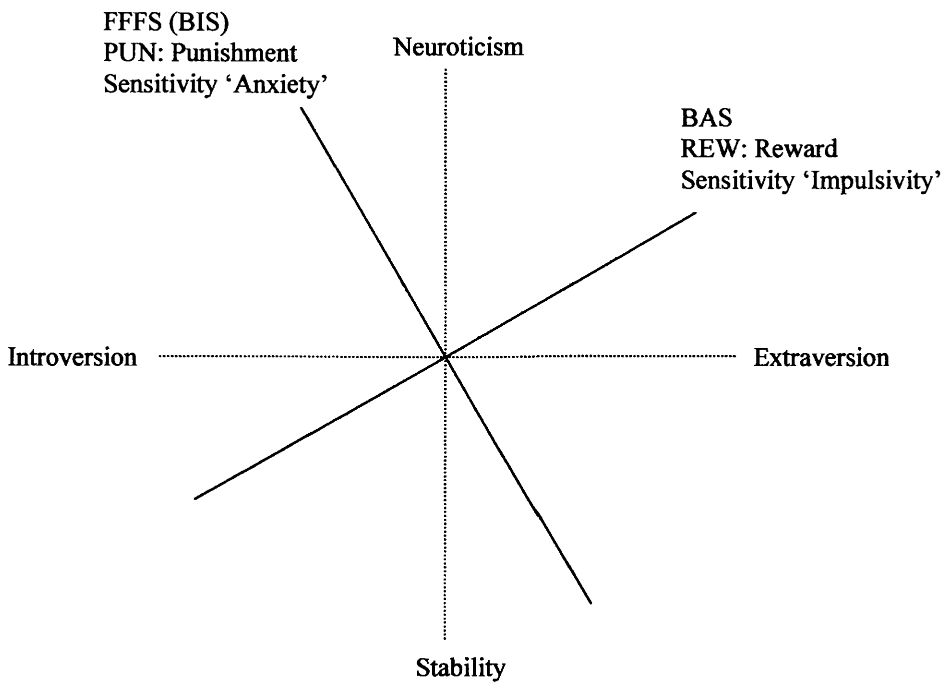


*Figure 1.2.* Position in factor space of the fundamental FFFS/BIS (PUN, punishment sensitivity) and BAS (REW, reward sensitivity) (unbroken lines) and the emergent surface expressions of these sensitivities, i.e., Extraversion (E) and Neuroticism (N) (broken lines). In the revised theory, a clear distinction exists between fear (FFFS) and anxiety (BIS), and separate personality factors may relate to these systems; however, for the present exposition, these two systems are considered to reflect a common dimension of punishment sensitivity. *Note.* Adapted from: "Reinforcement Sensitivity Theory and Personality," by P.J. Corr, 2004, *Neuroscience and Biobehavioural Reviews, 28,* p. 319; *The Reinforcement Sensitivity Theory of Personality* (p. 6), by P.J. Corr, 2008, Cambridge: Cambridge University Press.

Gray related Eysenck's extravert to someone with an overactive BAS and an under active BIS. The BIS, in terms of Eysenck's Extraversion scale, ranges from E-/N+ (Anx+) to E+/N- (Anx-; Anx+ is rotated by 30° from N; Gray, 1970; Pickering et al.; see Figure 1.2). Gray related Eysenck's introvert to someone with an overactive BIS and an under active BAS. Experimental support exists for RST's predicted association of introversion-extraversion and reinforcement (e.g., Boddy, Carver, & Rowley, 1986; Gupta, 1976, 1990; Gupta & Nagpal, 1978; Gupta & Shukla, 1989; Kantorowitz, 1978; McCord & Wakefield, 1981; Nagpal & Gupta, 1979; Seunath, 1975).

RST has been refined and revised throughout the years as more and more research has been conducted. As a result, the concept of the FFS now not only incorporates freezing (leading to it being renamed the Fight-Flight-Freeze System; FFFS; Gray & McNaughton, 2000, p. 86), which occurs when faced with unavoidable actual threat stimuli (the presence of avoidable actual threat stimuli leads, depending on the situation, to either anger-related fight or fear-related flight) but this system is also now hypothesised to be activated by *all* forms of aversive stimuli: unconditioned, innate and conditioned. The distinction between conditioned and unconditioned stimuli with regards to the BIS and the BAS has also been blurred by the revised version of the model (Gray & McNaughton). According to revised (2000) RST, the BAS is now hypothesised to be activated by *all* forms of appetitive stimuli, conditioned and unconditioned, and the BIS is now responsible for resolving goal conflict in general (e.g., approach-avoidance conflict; rather than for mediating reactions to conditioned aversive stimuli and innate fear stimuli). Mischel et al. (2004. p. 354) offers a helpful description of the BIS: 'You can think of it as a withdrawal-avoidance system that allows one to pause and then contemplate alternatives before taking action'.

In broad terms, RST now postulates that individuals with heightened FFFS activity are most sensitive to punishment and so are most motivated by this form of stimulation; individuals with heightened BAS activity are most sensitive to reward and so are most motivated by this form of stimulation; and individuals with heightened BIS activity are most sensitive to goal conflict. Specific differences aside, both Gray's (1982) original theory and revised RST (Gray & McNaughton, 2000) would still seem to predict that:

> On average, impulsive (ex hypothesi, strong BAS) individuals should be most sensitive to signals of reward, relative to nonimpulsive (ex hypothesi, weak BAS) individuals; and anxious (ex hypothesi, strong BIS) individuals should be most sensitive to signals of punishment, relative to nonanxious (ex hypothesi, weak BIS) individuals. (Corr, 2002b, p. 513)

There is some speculation as to whether the BIS and BAS systems interact to produce behavioural outcomes or whether they are separate systems independent of one another in their effects. The perspective most common among RST studies, and which was adopted for use in the studies in the present thesis, is the latter of these and has been named the 'separable subsystems hypothesis' (Corr, 2001, 2002b). This approach suggests that each system, both BIS and BAS, function independently from one another and, therefore, just one system must be in exclusive control at any one time. According to the separable subsystems hypothesis, responses to reward should be the same at all levels of Anx and responses to punishment should be the same at all levels of Imp (see Corr, 2001, 2002b). Individual differences in BIS and BAS brain reactivity could potentially help explain individual differences in inhibitory control and performance on the stop-signal task, particularly across tasks with different response contingencies.

Since, in the stop-signal paradigm, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), it would be reasonable to expect individuals with heightened BAS activity (postulated to be most sensitive to reward and so most motivated by this form of stimulation) to be more motivated in approaching the go-signal (particularly if the potency of this rewarding stimulus were to be strengthened) and, therefore, less likely to inhibit this approach response in the presence of stop-signals (i.e., show weaker inhibitory control) than individuals with weak BAS activity. In contrast, it would be reasonable to expect individuals with heightened BIS activity as well as individuals with heightened FFFS activity (postulated to be most sensitive to signals of punishment) to be more motivated in inhibiting responses to punishing stop-signals (particularly if the potency of this punishing stimulus were to be strengthened) than individuals with weak BIS/FFFS activity.

Newman, Wallace, Schmitt, and Arnett (1997) developed what has become known as a face valid, behavioural assessment device for the measurement of BIS functioning (see Pickering et al., 1997). The 'Q-task' (described in detail in chapter 2, section 2.1.2) is computer-based and comprises two phases; the first of which establishes the letter Q as a punishment cue to provide an input to the BIS. This is achieved through administration of 150 trials in which the participant must inhibit a response (button presses) in the presence of the letter Q in order to avoid punishment. The extent to which this conditioned aversive stimulus inhibits behaviour is then examined in phase 2. In the second phase, a visual search task is presented, involving go- (requiring a button press response) and stop- (requiring inhibition of the button press response) trials, in which the letter Q is irrelevant but appears on 50% of go-trials with the expectation that response latencies on these trials should be generally slower than on go-trials with no Q. It is possible to measure the degree to which the Q elicited behavioural inhibition in this second phase by subtracting the participant's mean response latency on Q-absent trials from their mean response latency on Q-present trials.

Using the Q-task, Newman et al. (1997) assessed BIS functioning by measuring whether approach responses were emitted more slowly when a cue for punishment was present. With the use of the trait form of the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970), Newman et al. demonstrated in a sample of undergraduate students that Anx+ (i.e., high BIS) participants responded more slowly than Anx- (i.e., low BIS) participants on Q-present versus Q-absent trials. Also, psychopaths were shown to display less inhibition than non-psychopathic controls (in a sample of incarcerated psychopaths and non-psychopaths subdivided into Anx+ and Anx- groups) on Q-present trials, consistent with weak BIS models of psychopathy (e.g., Fowles, 1980; Gray, 1987), but only when comparing Anx+ psychopaths with Anx+ controls. In relation to the aims of the present thesis, it was felt that this face valid, behavioural assessment device for the measurement of BIS functioning (Pickering et al., 1997) might be a potentially useful tool to be administered alongside the stop-signal paradigm.

*1.2.2 Personality and inhibitory control*

The bulk of previous studies using the stop-signal paradigm have focused on inhibitory control in children with AD/HD (e.g., Jennings et al., 1997; Oosterlaan & Sergeant, 1998; Overtoom et al., 2002; Schachar & Logan, 1990) and many studies have demonstrated that AD/HD children show impaired inhibitory control (e.g., Aman, Roberts, & Pennington, 1998; Daugherty, Quay, & Ramos, 1993; Jennings et al., 1997; Oosterlaan & Sergeant, 1996; Schachar & Logan, 1990; Schachar & Tannock, 1995; Schachar, Tannock, Marriott, & Logan, 1995). The personality trait of impulsivity is assumed to be a major characteristic of AD/HD (Diagnostic and Statistical Manual of Mental Disorders fourth edition; *DSM-IV*; American Psychiatric Association; APA; 1994). According to the *DSM-IV*, impulsivity manifests itself as: (1) difficulty in delaying responses, blurting out answers before questions have been completed; (2) difficulty awaiting one's turn; and (3) frequently interrupting or intruding on others to the point of causing difficulties in social, academic or occupational settings. Individuals with deficient inhibitory control react impulsively in situations in which controlled behaviour is required.

The relationship between impulsivity and inhibitory control has been studied under a number of different experimental conditions in previous personality research. When compared with low impulsive (Imp-) participants, highly impulsive (Imp+) participants may be characterised as showing impaired response inhibition in the circle drawing paradigm when cues of reward are present (Bachorowski & Newman, 1990; Wallace & Newman, 1990), by making less omission errors and more incorrect responses in multiple choice examinations (Avila, Molto, Segarra, & Torrubia, 1995), by making more commission errors in approach avoidance conflicts using the go/no-go discrimination task (Avila et al., 1995; Patterson, Kosson, & Newman, 1987), and by displaying a preference for immediate rather than delayed, greater reward in a choice task (Avila & Parcet, 2000). The studies just mentioned have indicated that impaired response inhibition has been shown to be related to impulsivity. This has led researchers to assume that Imp+ individuals should demonstrate impaired inhibitory control as compared to Imp- individuals in the stop-signal paradigm (Avila & Parcet, 2001; Logan et al., 1997; Rodriguez-Fornells et al., 2002).

It has been suggested that impaired response inhibition is observed in impulsive subjects when they should inhibit a strongly established response for reward (Patterson & Newman, 1993). Logan et al. (1997) found a significant relation between impulsivity and inhibitory control in a sample of 136 undergraduate students; Imp+ participants had slower stop-signal reaction times (i.e., weaker inhibitory control) than Imp- participants. Since the stop-signal task involves a dominant (rewarding, according to Avila & Parcet, 2001) go-task, Logan et al.'s findings support Patterson and Newman's suggestion since they would expect this dominant go-task to impair impulsive subjects' processing of a secondary cue such as the stop-signal, producing a deficit in inhibitory control. Positively reinforcing the dominant go-task with specific rewarding stimuli should, therefore, result in even weaker inhibitory control observed in impulsive participants since they would be required to inhibit an even more strongly established response for reward.

In Rodriguez-Fornells et al.'s (2002) study (described in section 1.1.1.1), the sample of twenty male participants tested on the two conditions (standard condition with no specific motivational stimuli and approach-avoidance conflict situation condition with specific rewarding and punishing stimuli) comprised ten imp+ and ten imp- participants. The aim of the study was to show that the approach-avoidance conflict situation created in the second condition should produce different involvement of the motivational systems (e.g., Gray's BIS or BAS), reflected in a different pattern of inhibitory control for impulsive groups. However, the authors found no significant differences between Imp+ and Imp- groups on any of the dependent measures assessed (probability of inhibition on stop-trials, SSRT, mean reaction time on go-trials, go-trial response accuracy) in either of the two conditions. The presence of mixed incentives in the second condition did, however, affect inhibitory control in low venturesomeness (i.e., low risk-taking) participants; the low risk-taking group's inhibitory control strengthened in the second condition compared to the first to a greater degree than did the high-risk taking group's inhibitory control. However, as well as being limited by small sample sizes, some of the methodology employed in Rodriguez-Fornells et al.'s study was flawed (as highlighted in section 1.1.1.1) and, as a result, any interpretation of their findings should be approached with caution.

Oosterlaan, Logan, and Sergeant's (1998) meta-analytic study of response inhibition on the stop-signal task in children with different psychopathologies (attention deficit/hyperactivity disorder; AD/HD, Conduct Disorder; CD, comorbid AD/HD + CD) found that impaired inhibitory control was present in children with AD/HD (proposed to be linked to an under-active BIS; see Quay, 1988, 1997), children with CD (proposed to be linked to an overactive BAS; Quay, 1988, 1997), and in those with comorbid AD/HD and CD, when compared with controls. Oosterlaan et al. also discovered that anxious children did not demonstrate enhanced inhibitory control, contrary to expectations.

Avila and Parcet (2001) studied the relationship between personality and inhibitory control in a sample of forty-five female students; each participant completed three personality questionnaires and performed a standard stop-signal task. The results produced significant associations between self-reported Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) scores and task performance: higher Sensitivity to Reward (SR) scale scores and lower Sensitivity to Punishment (SP) scale scores were associated with general inhibitory deficits. The SP scale of the SPSRQ is designed to measure Gray's BIS and the SR scale is designed to measure the BAS (Torrubia et al. 1995). Thus, Avila and Parcet demonstrated that impaired inhibitory control on the stop-signal task was related to Gray's BIS and BAS in that high BAS and low BIS were associated with general inhibitory deficits.

Avila and Parcet (2001) concluded that their results and the results from previous studies (Avila & Parcet, 2000; Patterson et al., 1987) 'suggest that an overactive BAS strongly predisposes to a poorer inhibitory control, and that this predisposition is independent of that due to an under-active BIS' (p. 984). Avila and Parcet also showed that the BAS was more associated with inhibitory control than the BIS, helping to shed light on why children with Conduct Disorder (i.e. an overactive BAS) show impaired inhibitory control and children with anxiety disorders (i.e. an overactive BIS) do not demonstrate an enhanced inhibitory control (Oosterlaan et al., 1998). However, it is possible that with the introduction of specific punishing stimuli to the stop-signal task, Anx+ (i.e., high BIS) may be shown to be related to stronger inhibitory control compared to on the standard task (no specific motivational stimuli).

#### *1.2.2.1 Summary*

Evidence exists in the literature for an association between impaired inhibitory control on the standard stop-signal task and the personality trait of impulsivity. Initial evidence for this association was based on the wealth of empirical research showing that children with AD/HD (a disorder with which the personality trait of impulsivity is assumed to be a major characteristic) demonstrate impaired inhibitory control on the task. Further, more specific, evidence has since been acquired (e.g., Logan et al., 1997) through splitting samples into highly impulsive (Imp+) participants and low impulsive (Imp-) participants, based on self-reported personality scores, and demonstrating that the Imp+ group show weaker inhibitory control on the task than the Imp- group. However, to date, Avila and Parcet (2001) have conducted the only study to explicitly link RST with performance on the stop-signal task; higher BAS activity and lower BIS activity were shown to be associated with weaker inhibitory control on a standard task. The authors argued that the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, p. 983), and, thus the results obtained provide promising theoretically consistent findings with the assumptions of RST.

It is suggested in the present thesis that, since RST brain behavioural system activity has been shown to be associated with inhibitory control on the standard task (no specific motivational stimuli), these theoretically consistent associations should be shown to be stronger on stop-signal tasks with specific motivational stimuli. For example, higher BAS activity should be shown to be more strongly associated with weaker inhibitory control on tasks with specific rewarding contingencies (associated with speeded responses on go-trials) than on the standard task. Also, while Avila and Parcet (2001) may have shown that the BAS was more associated with inhibitory control than the BIS on the standard task, it is possible that the BIS may be shown to be more associated with inhibitory control than the BAS on tasks with specific punishing contingencies (associated with not stopping for stop-signals). Rodriguez-Fornells et al.'s (2002) attempt to show that the presence of mixed incentives on the task should produce different involvement of the BIS or the BAS was limited by methodological problems and, therefore, it is argued that further research is necessary to provide more reliable findings.

While a wealth of studies have investigated inhibitory control in children with AD/HD (an impulse control disorder) using the stop-signal paradigm, to date, no previous research has used the paradigm to investigate inhibitory control in pathological gamblers (another well-known, but little-understood, impulse control disorder). Gambling behaviour is discussed in the next section.

### 1.3 Gambling behaviour

There is no clear and universally accepted definition of gambling, since it is usually defined in law by the specific type of gambling activity undertaken (e.g., betting, gaming, lotteries etc.). However, generally it requires at least two people (normally an operator and an individual), risking a stake (usually money) on the outcome of a future event, the result of which is uncertain and partly determined by chance. The majority of people who gamble do so for pleasure and are restrained in their behaviour. They derive pleasure from this activity and do not suffer any personal or financial difficulties as a result of their gambling. However, a minority of people encounter difficulties and have a problem in moderating their gambling behaviour to match their financial situation. While many different definitions exist for 'problem gambling', most agree that the consequences disrupt, compromise and/or damage personal, occupational, family and/or recreational pursuits (Griffiths, 2004).

Results from the British Gambling Prevalence survey (Sproston, Erens, & Orford, 2000) showed that just less than one percent of the UK adult population are problem gamblers. However, the most recently amended legislation of UK gambling activity (Gambling Act 2005) has greatly increased society's opportunity to participate in this form of behaviour. Under Britain's 1968 Gaming Act, casinos operated as private member's clubs and gamblers had to apply for membership 24 hours before they could enter. The new legislation has abolished this rule and has relaxed restrictions on gambling behaviour and advertising in the UK. Since it is likely that this change in legislation could lead to an increased prevalence of problem gambling, and thus a greater number of individuals experiencing gambling related problems, it is important that much research is carried out with the aim of better understanding this apparently paradoxical, harmful, problem behaviour.

### *1.3.1 Personality, gambling behaviour, and inhibitory control*

In 1980, pathological gambling (PG) was included in the *DSM-III* (APA, 1980) as one of the 'Impulse Control Disorders'; since then, evidence has been produced relating impulsivity to PG both in research using behavioural tasks as well as in research using self-report personality questionnaires. For example, pathological gamblers have been shown to discount delayed rewards more rapidly (an indicator of impulsivity) than control participants on a delay discounting task (Dixon, Marley, & Jacobs, 2003), to make more impulsive decisions on the Iowa Gambling Test (IGT) than control participants (Cavedini, Riboldi, Keller, D'Annucci, & Bellodi, 2002), and, although some initial studies using questionnaire measures did not find any relationship between PG and impulsivity (e.g., Allcock & Grace, 1988), most confirmed an important association (Blaszczynski, Steel, & McConaghy, 1997; Carlton & Manowitz, 1994; Castellani & Rugle, 1995; McCormick, Taber, Kruedelbach, & Russo, 1987; Potenza et al., 2003) using questionnaires such as the Barratt Impulsivity Scale or the Eysenck Impulsiveness Scale I.7.

Different neurobiological studies have also associated PG with impulsivity (e.g., Blanco, Orensanz-Munoz, Blanco-Jerez, & Saiz-Ruiz, 1996; Carrasco, Saiz-Ruiz, Hollander, Cesar, & Lopez-Ibor, 1994; DeCaria et al., 1996; Nordin & Eklundh, 1999), and, from a genetic perspective, certain polymorphisms that have been shown to be associated with disorders characterised by a marked impulsiveness component have also been found to be associated with PG. For example, the *TaqI* A1 polymorphism linked to the *DRD2* gene has been found to be associated with PG (Comings et al., 1996) as well as with alcoholism (Blum et al., 1990; Noble, 2003), AD/HD (Comings et al., 1991), and antisocial traits (Ponce et al., 2003).

McCormick (1993) compared substance abusers with a pathological gambling problem with substance abusers without a pathological gambling problem on two psychological constructs. One of the constructs McCormick (1993) labelled 'behavioural disinhibition', which refers to the inability to inhibit behaviour, even when such behaviour is detrimental, in the long run. Since all gambling forms are intrinsically biased against the gambler, they are highly likely to be detrimental to the gambler if behaviour is not appropriately moderated and restrained. McCormick's study found 'a constant, direct relationship between the severity of the subject's gambling problem and measures of impulsivity and the disinhibition of aggression and hostility' (McCormick, 1993, p. 335). A significant positive relationship was found between impulsivity and gambling severity.

In addition to impulsivity, previous studies have attempted to link gambling behaviour to the 'sensation-seeking' personality factor identified by Zuckerman (1979, 1994). Sensation-seekers are described as individuals who seek novel, complex or varied sensations or experiences and are willing to take risks for the sake of such experience. The arousal or excitement produced by gambling activity is rewarding to the high sensation-seeker, and, therefore, an arousal theory of gambling would suggest that the monetary risk and uncertainty of gambling provides a higher level of stimulation and arousal which high sensation-seekers desire (Zuckerman, 1994). However, evidence to support associations between sensation-seeking and gambling behaviour is rather sketchy. Various studies have failed to identify any associations between them (e.g., Blaszczynski, McConaghy, & Frankova, 1990; Blaszczynski, Wilson, & McConaghy, 1986; Breen & Zuckerman, 1999). However, one consideration, as noted by Coventry and Brown (1993), is that gamblers become specialists, concentrating all their efforts in just one arousal seeking activity (gambling) and would, therefore, be unlikely to score highly on a sensation-seeking scale involving a variety of sensation-seeking activities.

RST provides a promising theoretical framework for understanding the motivational dynamics underlying PG, since gambling presents individuals with both desirable goals (i.e., winning money) as well as punishment (i.e., losing money) and thus gambling should potentially activate the brain behavioural systems described by RST. In fact, Gray was appointed psychology expert on the Royal Commission on Gambling just prior to his death in 2004. However, at the time of writing, no previous research has investigated explicit links between RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity and PG.

Since, as discussed above, there is strong evidence relating impulsivity (proposed to be linked to the BAS; see Corr, 2004) to PG, this would lead to the suggestion that, within the context of RST, the disinhibited behaviour characterised by PG may result from hyper-sensitivity to reward. It would be reasonable, therefore, to expect pathological gamblers to be more highly BAS reactive than non-problem gamblers. However, since gambling not only presents potential reward but also potential punishment (to a greater degree even than reward, particularly in the long term), it seems likely that dysfunctions of impulse control characterised by PG may also result from distortions of the FFFS and the BIS. RST predicts that, as well as resulting from hyper-sensitivity to reward, disinhibited behaviour may also result from hypo-sensitivity to punishment.

It has been argued that problem gamblers are insensitive to punishment in that they fail to cease gambling despite losses, and demonstrate a tendency to persist in gambling/performing more poorly (compared to controls) on decision-making tasks despite potential future punishment (Vitaro, Arseneault, & Tremblay, 1999). It would be reasonable, therefore, to expect pathological gamblers to be less highly FFFS/BIS reactive than non-problem gamblers. Since the BIS is proposed to be involved in the regulation of goal-conflict detection and resolution it seems likely that a dysfunction in this system might explain why certain individuals gamble to excess while others (the vast majority) can control their gambling behaviour and do not experience gambling related problems.

In terms of investigations into PG and inhibitory control, previous studies have used behavioural tasks such as the go/no-go task (Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2005) and the delayed response task (Dixon et al., 2003). Goudriaan et al. demonstrated that go/no-go performance was impaired (indicating impaired response inhibition) in pathological gamblers compared to controls and Dixon et al. similarly showed that pathological gamblers discounted delayed rewards more rapidly than controls on the delayed response task. However, although these tasks measure some facet of the response inhibition process or impulsive behaviour, the precise mechanisms underlying impaired response inhibition on such tasks are not completely known and, unlike the stop-signal task, they do not afford measurement of the underlying inhibitory control process.
In addition, the go/no-go task and the delayed response task have been criticised for their poor construct validity or reliability (Halperin, McKay, Matier, & Sharma, 1994; Kindlon et al., 1995; Oosterlaan et al., 1998). It is possible for performance on these tasks to be influenced by a wide array of factors such as age or intelligence quotient (IQ) and, therefore, unlike the stop-signal tasks valid and reliable measure of the inhibition process (Kindlon et al., 1995; Logan, 1994), these tasks could not be considered pure measures of the inhibitory control process.

Despite growing evidence of the association between impaired inhibitory control and PG, the stop-signal task (standard version, let alone stop-signal tasks with specific motivational stimuli) has yet to be utilised for the examination of inhibitory control in pathological gamblers. Since the task affords measurement of the underlying inhibitory control process, its use has the potential to advance knowledge and understanding of pathological gamblers' inhibitory control, and any apparent impairment in this important self-regulating function.

*1.3.1.1 Summary*

Pathological gambling (PG), classified as an impulse control disorder, has consistently been shown to be associated with impulsivity as a personality dimension. Previous studies have also attempted to link gambling behaviour to the sensation-seeking personality factor, but with less consistent findings. Despite RST providing a promising theoretical framework for understanding the motivational dynamics underlying PG, at the time of writing, no previous research has investigated explicit links between RST brain behavioural system activity and this particular impulse control disorder. Such empirical investigation could contribute valuable information to the understanding and explanation of the disinhibited behaviour characterised by PG. Although there is growing evidence of the association between impaired inhibitory control and PG, this evidence has been gathered based on performance of behavioural tasks that, unlike the stop-signal paradigm, could not be considered pure measures of the inhibitory control process. The stop-signal task has yet to be utilised for this purpose and it is suggested in the present thesis that, since the task affords measurement of the underlying inhibitory control process, its use has the potential to advance knowledge and understanding of pathological gamblers' inhibitory control.

The stop-signal task does not measure inhibitory control specific to gambling behaviour. Therefore, in order to investigate further gambling related inhibitory control and its association with personality in normal as well as pathological gamblers, a number of other behavioural tasks, designed to be ecologically valid gambling tasks, were investigated to be used alongside the stop-signal task (as well as the Q-task) in the present thesis. These tasks are presented in the following section.

### *1.3.2 Assessing gambling related inhibitory control*

Commercial gaming establishments, such as casinos, offer a variety of games (e.g., video poker, slot machines, blackjack, roulette etc.) from which gambling behaviour can be evaluated. However, it is problematic in the casino industry to conduct field research in which variables of interest in these games (e.g., probability of winning, reinforcement magnitude, or delay of reinforcement) are manipulated since these games are either designed and government regulated to be purely probabilistic (i.e., based on an intermittent schedule of reinforcement) or, like many card and table games, they have set odds that cannot be manipulated. Controlled experimental research on gambling behaviour has become feasible due to technological advances in computer software and design (MacLin, Dixon, & Hayes, 1999). Computerised gambling simulations are potentially useful tools in the investigation of gambling behaviour since they can allow for manipulation of variables of interest in a controlled laboratory setting. They can be used as ecologically valid gambling tasks for the measurement of gambling behaviour on a trial-by-trial basis, and allow for controllable crucial variables of interest that may influence size of bets made, duration of play, and/or time between bets placed while gambling.

The card perseveration (CP) task (Newman, Patterson, & Kosson, 1987) is a viable example of a computerised gambling task (described in detail in chapter 2, section 2.1.3), designed to assess the ability of an individual to adjust a previously rewarded behavioural response to a decreasing rate of reward and increasing rate of punishment. Specifically, the CP task is used to assess response perseveration (i.e., a lack of response inhibition) which refers to 'the tendency to persist in making previously rewarded responses that have become maladaptive (i.e. punished)' (Vitaro et al., 1999, p. 569). To perform well on the CP task requires 'response modulation' (Newman & Lorenz, 2001), described by Newman and Wallace (1993, p. 700) as entailing 'a brief shift of attention from the organization and implementation of goal-directed behavior to stimulus evaluation'.

Failure of response modulation results in poor performance on the CP task, leading to perseveration: continuing to play when the ratio of wins to losses is clearly no longer positive (Newman et al., 1987). Newman and Wallace (1993) explain a reduced tendency to interrupt goal-directed behaviour to evaluate its potential negative consequences as the result of a greater 'reward dominance' (i.e., greater sensitivity to reward than to punishment). The ability to pause and reflect, hindered by reward dominance, is an important ability for regulating impulsive behaviour. Reward dominant individuals are less likely to evaluate the suitability of behaviour in immediate situations and to associate this behaviour with punishment and other forms of aversive feedback and, therefore, they are less likely to inhibit this behaviour, even if it is maladaptive, in the future. Reward dominance can be explained in the context of RST as a heightened BAS activity and a suppressed BIS activity (see Gray, 1991), thus response perseveration on the CP task should be shown to be associated with RST brain behavioural system activity.

Another potentially useful and ecologically valid computerised gambling task for the investigation of gambling related inhibitory control is the slot machine simulation. Research has found that of all the games played in casinos, the slot machine is the biggest revenue maker (Ghezzi, Lyons, & Dixon, 2000). This may be partly due to the slot machines simplicity of design and ease of play since the literature on gambling (e.g., Petry & Roll, 2001) suggests that decreasing the effort required to gamble will increase the probability of gambling. Very few rules need to be learned in order to play the slot machine: (1) insert coin(s); (2) pull the lever; and (3) wait to see if you have won. Modern slot machines are video based, as opposed to having actual reels inside the machine and a lever to pull down like the old models, and so computerised slot machine simulations capture realistic qualities of modern casino slot machines.

#### *1.3.2.1 Previous studies using the card perseveration (CP) task*

Numerous studies have used the CP task and similar decision-making tasks to demonstrate a relationship between response perseveration and externalising forms of maladjustment. These studies have differentiated normal controls from oppositional defiant and conduct disordered children and adolescents (Fonseca & Yule, 1995; Matthys, van Goozen, Vries, Cohen-Kettenis, & van Engeland, 1998; O'Brien & Frick, 1996; Shapiro, Quay, Hogan, & Schwartz, 1988; van Goozen, Cohen-Kettenis, Snoek, Matthys, Swaab-Barneveld, & van Engeland, 2004), pathological gamblers (Goudriaan et al., 2005), adolescents with psychopathic tendencies (Fisher & Blair, 1998; Séguin, Arseneault, Boulerice, Harden, & Tremblay, 2002), and adult psychopaths (Newman & Kosson, 1986; Newman, Patterson, Howland, & Nichols, 1990; Newman et al., 1987; Newman & Schmitt, 1998; Thornquist & Zuckerman, 1995).

Breen and Zuckerman (1999) gave participants (248 male undergraduates who gambled) US$10 cash and the opportunity to use this money to gamble on a computer-generated gambling program, based on Newman et al.'s (1987) CP task. Those participants who decided not to gamble were termed 'NonPlayers'; those who gambled and quit with cash left were termed 'NonChasers'; and those who played the task until they lost all available money were termed 'Chasers' (Breen & Zuckerman, 1999, p. 1097). Breen & Zuckerman produced results suggesting that individual differences in impulsivity discriminated Chasers from NonChasers on their version of the CP task: Chasers scored significantly higher on Zuckerman's impulsivity factor (from the Zuckerman-Kuhlman Personality Questionnaire; ZKPQ; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993) than NonChasers.

Newman et al. (1987) investigated group differences in response perseveration between psychopaths and non-psychopaths. Both groups performed the task under three different conditions: (1) with immediate feedback only (i.e., 'standard' task); (2) with a display illustrating their cumulative response feedback; and (3) with a display illustrating their cumulative response feedback accompanied by a 5-s waiting period during which participants were prevented from making another response. This third manipulation, forcing participants to wait 5-s following response feedback, was imposed based on previous research (Patterson, Kosson, & Newman, 1987) indicating that disinhibited participants, including psychopaths, are less likely than controls to pause after receiving negative feedback and that failure to pause following punishment is related to poorer learning from punished errors.

The aim of Newman et al.'s (1987) study was to explore manipulations that might reduce response perseveration in psychopaths. Their results showed that, as predicted, the group of psychopaths played significantly more cards and lost more money (i.e., displayed a greater response perseveration) than did the group of non-psychopaths when the task involved immediate feedback only. The addition of a display illustrating participants' cumulative feedback did little to reduce this difference. However, when participants played the task with a cumulative feedback display accompanied by a 5-s waiting period during which they were prevented from making another response, Newman et al. found no group differences. Their results also showed that the control group played fewer cards and won more money in this third condition than they did in condition 1 (immediate feedback only).

Newman et al. (1987) did not, however, include a condition with immediate feedback only accompanied by a 5-s waiting period during which no responses could be made. The 5-s waiting period was accompanied by a cumulative feedback display in Newman et al.'s study and, therefore, it is unclear as to whether or not the 5-s waiting period would have had the same effects without the presence of a cumulative feedback display. The authors 'reasoned that forcing subjects to pause after response feedback would improve their use of information about the changing probability of punishment and would reduce perseveration' (Newman et al., 1987, p. 146) and they produced evidence to support this idea. However, it is possible that perseveration could be reduced through forcing participants to pause after response feedback even without the presence of a cumulative display of information about the changing probability of punishment.

Goudriaan et al. (2005) administered the CP task to a PG group and a normal control group in an attempt to show that pathological gamblers should perseverate for reward to a greater degree than non-pathological gamblers. Goudriaan et al. based this hypothesis on previous research showing that groups with disinhibited behaviour, such as children with externalising behavioural disorders and adult male psychopaths, showed greater response perseveration than controls on the CP task (Daugherty & Quay, 1991; Fonseca & Yule, 1995; Kindlon, Mezzacappa, & Earls, 1995; Newman et al., 1987). Since PG has been linked to 'behavioural disinhibition' (McCormick, 1993) it was argued that pathological gamblers should perseverate on the CP task also. The results showed that the PG group did perseverate longer on the CP task compared to the normal control group. Goudriaan et al. also found that the PG group did not slow down following losses compared to following wins on the task, whereas the normal control group did slow down following losses compared to following wins. The authors explained this finding as evidence that pathological gamblers showed deficient feedback processing following losses on the CP task as compared to the normal control group: the normal control group deliberated longer about whether to continue or to quit playing the task after experiencing a loss than did the pathological gambling group.

*1.3.2.1.1 Summary*

Evidence has been produced, using a version of Newman et al.'s (1987) standard card perseveration (CP) task, to suggest that the personality trait of impulsivity is associated with response perseveration on this computerised gambling task. However, despite the tasks specific rewarding and punishing reinforcement contingencies, to date, no previous research has investigated explicit associations between RST brain behavioural system activity and CP task performance. A standard version of the task has, however, been used to investigate pathological gamblers' response perseveration compared to non-pathological gamblers'; finding that, as expected and consistent with growing evidence of the association between impaired inhibitory control and PG, pathological gamblers perseverated longer (i.e., demonstrated weaker response inhibition) compared to controls.

Newman et al. (1987) demonstrated that while psychopaths (another group, like pathological gamblers, characterised by disinhibited behaviour) perseverated to a greater degree than non-psychopaths on the standard task (immediate feedback only), this relative perseverative deficit was reduced on the task with a cumulative feedback display accompanied by a 5-s waiting period during which participants were prevented from making another response. Although it is unclear as to whether or not this effect was due to the forced 5-s waiting period alone or the combination of the waiting period together with the cumulative feedback display, Newman et al. not only demonstrated that it is possible to reduce psychopaths' perseveration (i.e., strengthen their response inhibition) but also that it is possible to reduce perseveration in normal controls. It would not only be valuable to investigate whether a forced 5-s waiting period alone (following immediate response feedback) would reduce response perseveration on the CP task but also whether, like psychopaths, pathological gamblers' relative perseverative deficit (Goudriaan et al., 2005) could be shown to be reduced in a similar manner. Such a finding could have potentially valuable implications for informing practice in the treatment of PG.

The limited amount of empirical research conducted using computerised slot machine simulations to investigate gambling behaviour is presented in the next section.

*1.3.2.2 Previous studies using slot machine simulations*

Since the birth of the computerised slot machine simulation, developed specifically for research in gambling behaviour (MacLin et al. 1999), several studies have employed them to investigate different aspects of gambling behaviour on an ecologically valid task (the slot machine). Weatherly, Sauter, and King (2004) tested the 'big win' hypothesis (which predicts that the development of PG can be explained in terms of a fallacious expectation of winning, created through experiencing an initial big win, which may then result in persistent gambling despite experiencing heavy losses) using a computer simulated slot machine and found that, contrary to this hypothesis, participants who experienced a large win on the first play quit playing the simulation earlier than participants who experienced a large win on the fifth play. Weatherly et al. explained their results from a behaviour analytic perspective, arguing that 'the intermittent nature of reinforcement in a gambling situation is what should lead to persistent gambling' (Weatherly et al., p. 502).

Weatherly and Brandt (2004) investigated participants' sensitivity to percentage payback (i.e., overall rate of reinforcement) and credit value (i.e., reinforcer magnitude). The authors manipulated these variables and tested the effects in two separate experiments; one using a between-subjects design and the other using a within-subjects design. It was argued that both experiments produced results demonstrating that participants' 'gambling behavior did not vary as a function of payback percentage' (Weatherly & Brandt, p. 33). However, the three payback percentages employed by Weatherly and Brandt (75%, 83% and 95%) were all relatively high rates of return and it could be argued that these values might not have been sufficiently different to significantly effect participants' gambling behaviour. It is possible that by employing more varied rates of return (e.g., 30%, 50%, and 70%) gambling behaviour would be shown to vary as a function of percentage payback. Any observed modifications in gambling behaviour resulting from these variations in overall rate of reinforcement could potentially be explained within the context of RST.

Schreiber & Dixon (2001) produced results showing that individuals' mean response latency between trials was faster following losing trials than it was following winning trials. Similar results have been observed on a computerised video poker simulation (Dixon & Schreiber, 2002) and on a real commercial slot machine in a casino-like laboratory (Dixon & Schreiber, 2004). These results were explained, in each case, through the concept of a negative reinforcement and avoidance paradigm (Hineline, 1977) whereby the losing trials are seen as aversive stimuli that cause the participants to initiate the onset of the next trial after the loss at a faster rate in an attempt to escape the continued presentation of the aversive stimuli. Another potential explanation for these findings, based on the assumptions of RST, would be that punishment induces physiological arousal which strengthens any ongoing behaviour (Gray, 1987), in these instances, the initiation of the onset of the next trial.

*1.3.2.2.1 Summary*

Previous studies have demonstrated that gambling behaviour can be studied empirically in a laboratory setting using computerised slot machine simulations. However, these studies are few to date and have tended to focus on gambling from a purely behaviour analytic perspective. It would be valuable, therefore, to utilise these ecologically valid gambling tasks for the investigation of associations between gambling behaviour and individual differences in reinforcement sensitivity (i.e., personality). Weatherly and Brandt's (2004) attempt to investigate participants' sensitivity to percentage payback (i.e., overall rate of reinforcement) produced results indicating that gambling behaviour does not vary as a function of this variable. However, it is suggested in the present thesis that through employment of more varied rates of return (e.g., 70% and 30%) than those used in Weatherly and Brandt's study, slot machine simulation performance (i.e., gambling behaviour) should be expected to vary as a function of percentage payback. It is possible that these variations could be shown to be different for pathological gamblers compared to non-problem gambling controls; providing data with which comparisons of gambling related inhibitory control could be drawn. The aims and hypotheses of the present thesis are presented in the following section.

## 1.4 Aims and hypotheses

*1.4.1 Aims*

This thesis aimed to investigate inhibitory control, reinforcement and personality, as well as implications for gambling behaviour. Toward this end, a number of experimental studies were conducted, each with their own specific aims and predictions, investigating various interrelated aspects contributing to the overall aims of this thesis. Where personality was being examined, a range of sensitive and standard self-report personality questionnaires were used (detailed in chapter 2, section 2.2). Inhibitory control was investigated using standard (no specific motivational stimuli) as well as modified (different specific reinforcement contingencies) versions of the stop-signal paradigm task, developed specifically for the purposes of the present thesis (detailed in chapter 2, section 2.1.1). Newman et al.'s (1997) Q-task was used to assess behavioural inhibition in relation to personality, inhibitory control, and gambling behaviour, and gambling related inhibitory control was investigated using a standard (immediate feedback only) as well as a modified (forced 5-s pause following immediate response feedback) version of the CP task developed specifically for the purposes of the present thesis (detailed in chapter 2, section 2.1.3) along with two different (in terms of percentage payback; i.e., overall rate of reinforcement) computerised slot machine simulations, also developed specifically for the purposes of the present thesis (detailed in chapter 2, section 2.1.4).

### *1.4.2 Hypotheses*

A number of interrelated hypotheses were generated based on the assumptions of the theories and the findings of the previous literature presented and discussed (in relation to the present investigation) in the above sections of this introduction. The hypotheses are outlined in the sections below. Each of the experimental tasks and psychometric measures of personality employed to test the hypotheses are presented in detail in the next chapter.

#### *1.4.2.1 Inhibitory control and reinforcement*

##### *1.4.2.1.1 Stop-signal task performance*

It was hypothesised that inhibitory control on the stop-signal task could be modified using different response contingencies (i.e., reinforcement). More specifically, since the standard task based on Logan's original has no specific motivational stimuli, although it could be argued that the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), it was hypothesised that: the introduction of specific punishing stimuli associated with response errors (including not stopping for stop-signals) should result in an increased care in task performance and, consequently, stronger inhibitory control on the task; the introduction of specific rewarding stimuli associated with speeded responses to the go-signal should result in an increased motivation in approaching this go-signal and, consequently, weaker inhibitory control on the task; and the introduction of the combination of both specific punishing and specific rewarding stimuli (thus creating an approach-avoidance conflict situation) should result in similar inhibitory control on the task (compared to on the standard task).

*1.4.2.1.2 Card perseveration (CP) task performance*

It was hypothesised that, on the CP task, imposing a forced 5-s waiting period alone (following immediate response feedback) should be sufficient in resulting in greater attention being paid to response feedback on each trial and thus an earlier awareness of the changing task contingencies and, consequently, lesser response perseveration (i.e., stronger inhibitory control) compared to on the standard task (no forced pause, immediate feedback only).

*1.4.2.1.3 Slot machine simulation performance*

It was hypothesised that computerised slot machine simulation performance (i.e., gambling behaviour) should be expected to vary as a function of percentage payback (i.e., overall rate of reinforcement).

*1.4.2.2 Personality in relation to inhibitory control, reinforcement, and behavioural inhibition*

It was hypothesised that self-reported sensitivity to reward/punishment (i.e., personality) should be associated with inhibitory control on each of the behavioural tasks employed. More specific hypotheses concerning these associations are presented in the following sections.

*1.4.2.2.1 Stop-signal task performance*

Since it could be argued that, in the stop-signal paradigm, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983) it was hypothesised that: higher self-reported BAS activity and Extraversion should be associated with weaker inhibitory control on the stop-signal task, and that these associations should be strongest on tasks with specific rewarding stimuli associated with speeded responses to the go-signal; and higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with stronger inhibitory control on the stop-signal task, and that these associations should be strongest on tasks with specific punishing stimuli associated with response errors (including not stopping for stop-signals).

*1.4.2.2.2 Card perseveration (CP) task performance*

It was hypothesised that, due to the CP tasks specific rewarding and punishing reinforcement contingencies, higher self-reported BAS activity and Extraversion should be associated with greater response perseveration (i.e., weaker inhibitory control) and, conversely, higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with lesser response perseveration.

*1.4.2.2.3 Slot machine simulation performance*

Due to the specific rewarding and punishing reinforcement contingencies present on the slot machine simulations it was hypothesised that higher self-reported BAS activity and Extraversion should be associated with more risky gambling behaviour (i.e., weaker inhibitory control) and, conversely, higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with less risky gambling behaviour.

*1.4.2.2.4 Q-task performance*

It was hypothesised that higher self-reported BIS activity should be associated with greater behavioural inhibition on the Q-task.

*1.4.2.3 Gambling, personality, inhibitory control, reinforcement, and behavioural inhibition*

It was hypothesised that pathological gamblers should be more highly BAS reactive and less highly FFFS/BIS reactive than non-problem gamblers, and that pathological gamblers should demonstrate impaired inhibitory control and less behavioural inhibition compared to non-problem gamblers on the behavioural tasks employed. More specific hypotheses concerning inhibitory control, reinforcement, and gambling are presented in the following sections.

*1.4.2.3.1 Stop-signal task performance*

It was hypothesised that pathological gamblers should demonstrate weaker inhibitory control compared to non-problem gamblers. Also, based on the predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was hypothesised that pathological gamblers' inhibitory control should be shown to be less strongly effected by the introduction of specific punishing stimuli (i.e., their inhibitory control should strengthen to a lesser degree) compared to non-problem gamblers' inhibitory control and that pathological gamblers' inhibitory control should be shown to be more strongly effected by the introduction of specific rewarding stimuli (i.e., their inhibitory control should weaken to a greater degree) compared to non-problem gamblers' inhibitory control.

*1.4.2.3.2 Card perseveration (CP) task performance*

It was hypothesised that pathological gamblers should perseverate longer (i.e., demonstrate weaker inhibitory control) on the standard CP task compared to non-problem gamblers but also that the imposition of a forced 5-s pause following immediate response feedback should reduce pathological gamblers' relative perseverative deficit.

*1.4.2.3.3 Slot machine simulation performance*

Based on the predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was hypothesised that pathological gamblers should demonstrate more risky gambling behaviour (i.e., weaker inhibitory control) across the slot machine simulations compared to non-problem gamblers and that pathological gamblers' slot machine simulation gambling behaviour should be less strongly effected by a reduction in percentage payback rate (i.e., an increase in the probability of being presented with a punishing trial should be less effective in moderating pathological gamblers' risky gambling behaviour) compared to non-problem gamblers' slot machine simulation gambling behaviour.

# Chapter 2

# Experimental Tasks and Psychometric Measures of Personality

This chapter details the experimental tasks and psychometric measures of personality employed in this thesis to investigate theory introduced in the preceding chapter (chapter 1). These materials are described in detail below so that references could simply be made to these descriptions in the experimental chapters to follow.

## 2.1 Experimental tasks

### *2.1.1 Stop-signal paradigm tasks*

Four computer based stop-signal paradigm tasks were developed, using E-Prime (version 1.2) software, to test the hypotheses: (1) the Baseline stop-signal task; (2) the Punishment stop-signal task; (3) the Reward stop-signal task; and (4) the Conflict (reward + punishment) stop-signal task.

#### *2.1.1.1 Baseline stop-signal task*

The Baseline task was designed to be a standard stop-signal task measuring baseline motor inhibition without specific motivational stimuli. The choice reaction time task designed for the Baseline task was similar to that used by Avila and Parcet (2001). It was presented on a PC computer screen, with the participant seated approximately 50-cm in front of the screen. The two components of the experimental task were the go-task and the stop-task (see Figure 2.1). The stimuli for the go-task were uppercase letters A, B, C, and D that subtended a visual angle of approximately 3.4° high x 2.1° wide. These stimuli were presented in the centre of the screen for 1000-ms followed by 1000-ms of blank screen. A 500-ms fixation point was also presented in the centre of the screen preceding these letters. The participant was required to make speeded responses with index and middle fingers of their preferred hand to the targets in the go-task. They were instructed to respond as follows: whenever the target letter was an A or a B they should press the '1' key on the keyboard number pad and whenever the target letter was a C or a D they should press the '2' key on the same keyboard number pad.

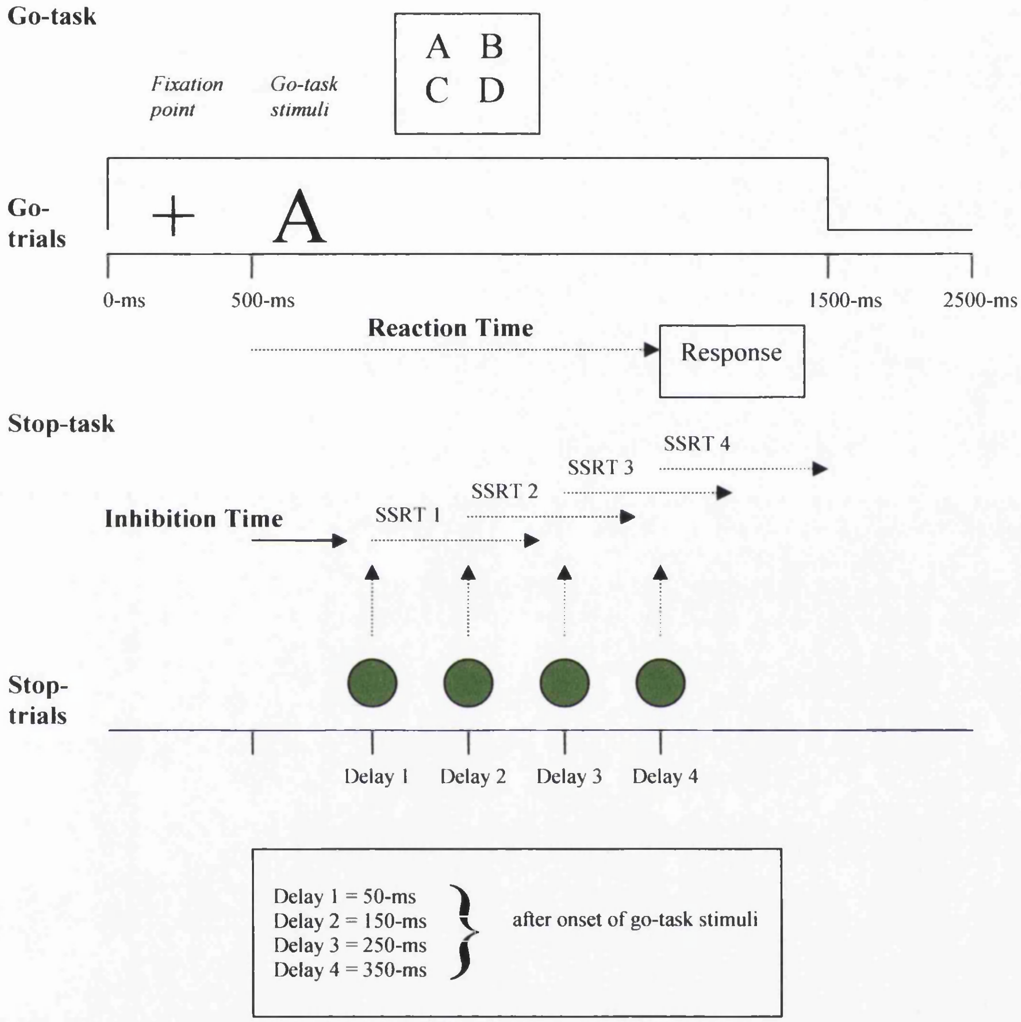


*Figure 2.1.* Stop-signal paradigm used in the present thesis with examples of go-task go-trials and stop-task stop-trials presented during the task. *Note.* SSRT = stop-signal reaction time, assumed to be constant in this representation; Adapted from: "Are high-impulsive and high risk-taking people more motor disinhibited in the presence of incentive?," by A. Rodriguez-Fornells, U. Lorenzo-Seva, and A. Andres-Pueyo, 2002, *Personality and Individual Differences*, *32*, p. 665.

The stop-task required the participant to inhibit responses to the stimulus in the go-task when a stop-signal appeared. This stop-signal appeared always delayed after the go-stimulus. The stop-signal used was a green circle with a diameter of 2.5-cm subtending 3.2° above the go-stimulus. The participant was instructed to inhibit their response to the go-task stimulus when the green circle was seen, but they were also told that this response inhibition was hard to make, and that they should not worry if they were unable to do it. It was explained to them that the stop-signal would occur at different delays, so sometimes they would be able to stop and sometimes they would not. The participant was specifically instructed not to wait for the stop-signal, and not to let the stop-task interfere with the go-task.

In order to familiarise the participant with the number keys and go-task stimuli, the Baseline stop-signal task began with a practise block of 20 go-trials without stop-signals. Following the practise block, the task comprised 192 trials conducted in 3 identical blocks separated by a 30-s rest pause. Stop-signals were presented on 25% of the trials; a quarter of the time with each letter of the go-task. Four stop-signal delays were used in the present study: 50, 150, 250 and 350-ms after the onset of a letter. The reason for using these particular delays was based on previous research using tasks with these delays showing that the probability of inhibiting decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms (Fillmore & Rush, 2002; Fillmore et al., 2001, 2002). These stop-signal delays were fixed across all participants. Each different letter in the go-task appeared the same number of times. The sequence of letters, stop-trials/go-trials, and stop-signal delays was random, and different random orders were administered to each participant.

*2.1.1.2 Punishment stop-signal task*

The Punishment task was designed to create an avoidance situation in which the participant performed the same experimental task as in the Baseline stop-signal task but was punished by losing points depending on their performance. Each time the participant failed to inhibit a response on stop-trials, responded with the wrong key, or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle) the computer screen appeared red and displayed the text "POOR! You lose 10 points!" in the centre of the screen for 1000-ms accompanied by an unpleasant "buzz" sound (a 22-kHz tone, 1000-ms in duration, generated by the external speakers of the computer) before the next trial began.

The participant was informed that their performance on this task would be monitored and compared with the average individual as a means of creating specific motivational stimuli and to increase their interest in the points. They were informed that points would be deducted for failing to inhibit a response when a stop-signal appears and for responding with the wrong key or failing to respond to the go-task (letters without a stop-signal). In addition, the participant was told that the more points they lost, the lower their overall score and performance would be for the task. No practise block was administered in the Punishment stop-signal task, just 192 trials conducted in 3 identical blocks separated by a 30-s rest pause.

#### *2.1.1.3 Reward stop-signal task*

The Reward task was designed to create an approach situation in which the participant performed the same experimental task as in the Baseline stop-signal task but was rewarded by winning points depending on their performance. Each time the participant responded with the correct key to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline stop-signal task) the computer screen appeared blue and displayed the text "GOOD! You win 10 points!" in the centre of the screen for 1000-ms accompanied by a pleasant "ring" sound (a 22-kHz tone, 1000-ms in duration, generated by the external speakers of the computer) before the next trial began.

The participant was informed that their performance on this task would be monitored and compared with the average individual as a means of creating specific motivational stimuli and to increase their interest in the points. They were informed that they would be awarded points for correctly responding quickly to the go-task (without a stop-signal). In addition, the participant was told that the more points they were awarded, the higher their overall score and performance would be for this task. No practise block was administered in the Reward stop-signal task, just 192 trials conducted in 3 identical blocks separated by a 30-s rest pause.

#### *2.1.1.4 Conflict stop-signal task*

The Conflict task was designed to create an approach-avoidance conflict situation in which the participant performed the same experimental task as in the Baseline stop-signal task but was rewarded and punished, by winning and losing points, depending on their performance. Each time the participant responded with the correct key to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline stop-signal task) the computer screen appeared blue and displayed the text "GOOD! You win 10 points!" in the centre of the screen for 1000-ms accompanied by a pleasant "ring" sound (a 22-kHz tone, 1000-ms in duration, generated by the external speakers of the computer) before the next trial began. Each time the participant failed to inhibit a response on stop-trials, responded with the wrong key or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle) the computer screen appeared red and displayed the text "POOR! You lose 10 points!" in the centre of the screen for 1000-ms accompanied by an unpleasant "buzz" sound (a 22-kHz tone, 1000-ms in duration, generated by the external speakers of the computer) before the next trial began.

The participant was informed that their performance on this task would be monitored and compared with the average individual as a means of creating specific motivational stimuli and to increase their interest in the points. They were informed that points would be awarded for correctly responding quickly to the go-task (without a stop-signal) and that points would be deducted for failing to inhibit a response when a stop-signal appears, for responding with the wrong key or failing to respond to the go-task (letters without a stop-signal). In addition, the participant was told that the more points they were awarded, the higher their overall score and performance would be for this task and the more points they had deducted, the lower their overall score and performance would be for this task. No practise block was administered in the Conflict stop-signal task, just 192 trials conducted in 3 identical blocks separated by a 30-s rest pause.

*2.1.1.5 Dependent measures of stop-signal task performance*

The important criterion measures of stop-signal task performance fall into two distinct categories: (1) measures of response inhibition; and (2) measures of response execution.

*2.1.1.5.1 Response inhibition*

Dependent measures of response inhibition on the stop-signal task are the variables of interest regarding participants' inhibitory control and they include: probability of inhibition on stop-trials and stop-signal reaction time (SSRT). To assess probability of inhibition on stop-trials, the proportion of successfully inhibited responses on the 48 stop-trials was calculated for each participant on each task. This provided a measure of mean probability of inhibition across each of the four stop-signal delays, ranging from a possible 1.00 for successfully inhibiting a response on 100% of stop-trials to 0.00 for failing to inhibit a response on all stop-trials, for each participant on each task. Smaller proportions of successfully inhibited responses indicated a lower probability of inhibiting a response to a stop-signal (i.e., weaker inhibitory control). The proportion of successfully inhibited responses was also examined at each stop-signal delay (i.e., proportion of inhibited responses to the 12 stop-signals presented at each of the four delays; 50-ms, 150-ms, 250-ms and 350-ms after the onset of go-stimuli) for each participant on each task.

Another dependent measure of response inhibition on the stop-signal task, SSRT, is the estimated mean time (in ms) required to inhibit responses to stop-signals. The method used for calculating

SSRT in the present study was first proposed by Logan (1981) and is based on the assumptions of the 'race model' (see Figure 2.2).

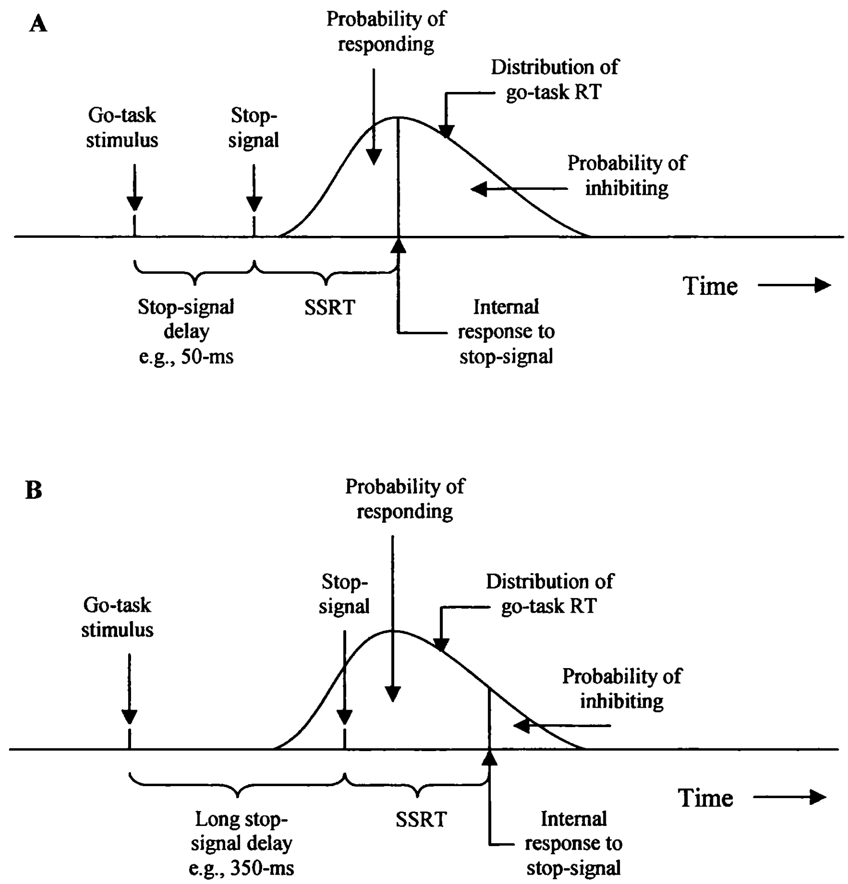


*Figure 2.2.* Graphic representation of the assumptions and predictions of the race model, indicating how the probability of inhibiting a response and the probability of responding to go-task stimulus on stop-trials depend on the distribution of go-task (go-trial) reaction times, SSRT, and stop-signal delay. Panel B exemplifies what happens when a long stop-signal delay is used, resulting in a reduced probability of inhibiting the response in that trial compared to trials in which a shorter stop-signal delay is used (panel A). *Note.* SSRT = stop-signal reaction time; RT = reaction time; Adapted from: "On the ability to inhibit thought and action: A theory of an act of control," by G.D. Logan and W.B. Cowan, 1984, *American Psychological Association, 91*, p. 300.

In the race model, SSRT is assumed to be the difference between the point at which the stop-signal was presented and the point at which the stopping process finished. The point at which the stop-signal was presented is known from the experimental protocol. The point at which the stopping process finished, however, is not known from the experimental protocol and has to be estimated from the observed probability of responding given a stop-signal and the observed distribution of go-trial reaction times. This involved collapsing go-trial reaction times into a single distribution and putting them in rank order. From this rank ordered distribution of go-trial reaction times, the *n*th reaction time was selected, where *n* was obtained by multiplying the number of reaction times in the distribution by the probability of responding at a given delay. According to Logan (1994, p. 215-216) 'the *n*th reaction time estimates the time at which the stopping process finished, relative to the onset of the go signal'. Stop-signal delay (the interval between the onset of the go-signal and the onset of the stop-signal) was subtracted from this value to give an estimate of SSRT (the time at which the stopping process finished relative to the onset of the stop-signal). This method was repeated for each stop-signal delay and then the four resulting values were averaged to yield a measure of mean SSRT for each participant on each task. A slower SSRT indicated a slower estimated time to inhibit a response (i.e., weaker inhibitory control).

#### *2.1.1.5.2 Response execution*

Dependent measures of response execution on the stop-signal task are yielded from responses displayed during go-trials (i.e., when no stop-signal occurs) and include: go-trial reaction time and go-trial response accuracy. To assess go-trial reaction time, reaction times (from correct and incorrect responses) to go-stimuli on the 144 go-trials were averaged for each participant on each task. This produced a mean reaction time (MRT) on go-trials (i.e., the average time from the onset of go-stimuli until a computer key press) for each participant on each task. No reaction time data were recorded for any non-responses (i.e., failing to respond to the go-stimulus on a go-trial) on the 144 go-trials on each task. To assess go-trial response accuracy, the number of response errors made on go-trials (i.e., pressing the incorrect key in response to the go-stimulus on a go-trial) was recorded for each participant on each task.

### *2.1.2 Q-task*

The Q-task was presented on a PC computer screen, with the participant seated approximately 50-cm in front of the screen, and consisted of two phases: (1) pre-treatment; and (2) test. In the first, pre-treatment, phase, the participant completed a total of 150 trials (two 75 trial segments separated by a 1-min rest period) in which they viewed a series of letter strings presented on the computer screen. In each trial, the letter string was always preceded by a 1000-ms fixation point ('*') and comprised either four or six of the following letters presented for 2000-ms: N, P, R, S, T, V, W, X, Z and Q. 50% of the trials presented four letter strings and 50% presented six letter strings, letters were 5-mm tall x 3-mm wide. The participant was instructed to respond to each letter string as quickly as possible, by pressing the spacebar on the computer keyboard, only when the letter Q was absent. They were instructed to press nothing at all when the letter Q appeared in the letter string. After each trial, the participant received a 1000-ms feedback display presented on the computer screen: 'Correct Response! You win x points' (where x was equal to 1, 2 or 3 points) and 'Wrong Response! You lose 5 points' after correct and incorrect responses, respectively, or 'Correct!' and 'Wrong!' after correct abstentations and misses, respectively. Instructions informed the participant that they would win one, two or three points depending upon how fast they responded and that they would lose five points if they pressed the spacebar when a Q was present. The letter Q was programmed to appear on a random 50% of the trials. This pre-treatment phase was designed to establish the letter Q as a cue for punishment which should result in behavioural inhibition. The extent to which this conditioned aversive stimulus inhibited behaviour was examined in a further 145 trials comprising the test phase.

Instructions for the test phase were presented onscreen following completion of the pre-treatment phase. In the test phase, the participant completed 145 trials (in one single block without a rest period) in which they were presented with a stimulus display containing four letters (or three letters and one number) arranged so that each character appeared in one corner of an imaginary rectangle that was 2.2-cm wide and 1.9-cm high at the outside border of the characters. In each trial, the stimulus display was composed of either three or four of the letters used in the pre-treatment phase (N, P, R, S, T, V, W, X, Z and Q) along with either one or none of the numerals 1-9. The participant was instructed to respond to each display as quickly as possible, by pressing the spacebar on the computer keyboard, only when all the symbols were letters and there was no number present. They were instructed to press nothing at all when a number appeared in the display. Instructions informed the participant that they would win three, four or five points depending upon how fast they responded and that they would lose five points if they pressed the spacebar when a number was present. Timing of the trials in the test phase was the same as in the pre-treatment phase. The experimental task was programmed to randomly produce approximately 40% go-trials (i.e., all letters, no number present) and 60% stop-trials (i.e., number present). The letter Q was programmed to appear on 50% of the go-trials, with the expectation that response latencies on these trials should be generally slower than on go-trials with no Q. Test phase trials differed importantly from pre-treatment phase trials in that the letter Q had no special relationship to task requirements in this phase of the experimental task.

#### *2.1.2.1 Dependent measure of Q-task performance*

The dependent measure of interest on the Q-task is Q-inhibition. Q-inhibition is a measurement of the degree to which the Q elicits behavioural inhibition in the test phase of the Q-task (after the Q has been established as a punishment cue in the pre-treatment phase). For each participant, response latencies on Q-absent trials in the test phase were averaged to produce a mean response latency on Q-absent trials and response latencies on Q-present trials in the test phase were averaged to produce a mean response latency on Q-present trials. Mean response latency on Q-absent trials was subtracted from mean response latency on Q-present trials to produce a measure of Q-inhibition for each participant.

*2.1.3 Card perseveration (CP) tasks*

Two computer based card perseveration (CP) tasks, designed in VB.net, were acquired to test the hypotheses: (1) a CP task with no forced pause between cards drawn (a standard CP task); and (2) a CP task with a forced 5-s pause between each card drawn.

*2.1.3.1 Standard task*

The CP task with no forced pause between cards drawn was designed to be a standard CP task measuring baseline response perseveration. This standard CP task was similar to that used by Newman et al. (1987). The task consisted of a deck of 100 playing cards, picture cards and number cards, presented face-down on a PC computer screen with the participant seated approximately 50-cm in front of the screen. As well as the deck of cards, a 'Draw' button and an 'Exit' button were displayed on the right-hand side of the computer screen. The amount of cash in dollars available to the participant throughout the task was also presented on the computer screen, below the deck of cards on the bottom left-hand side of the screen. The task was programmed to display these playing cards face-up, one at a time, each time the participant clicked on the 'Draw' button until either (1) the participant clicked on the 'Exit' button to end the task or (2) the participant played through all 100 cards. Each time the participant drew a picture card (i.e., Jack, Queen, King or Ace) the computer displayed the message 'You Win!' and $10 was added to the participant's cash. Each time the participant drew a number card (i.e., 2-10) the message 'You Lose' was displayed on the screen and $10 was subtracted from the participant's cash.

Each participant began the task with $100. The 100 cards were arranged in a pre-programmed order so that the probability of drawing a winning card (picture card) decreased by 10% after every block of 10 cards. The probability of drawing a winning card was set at 90% for the first block of 10 cards and so decreased to 0% for the final block of 10 cards. The order of the picture cards and the number cards was random within each block of 10 cards, and different random orders were administered to each participant. The participant won the greatest amount of cash ($350) if they clicked on the 'Exit' button after drawing approximately half of the cards, before the probability of losing became greater than the probability of winning. If the participant drew all 100 of the cards, they lost all of their winnings, including the $100 with which they began the task.

Unlike Newman et al.'s (1987) CP task, the participant was not playing to keep the amount of cash they won on exiting the standard CP task. Instead, they were informed that although the cash they were playing for was not real money, the amount of cash they finished the game with would be compared to the average individual's winnings and that they should try to finish the game with as much cash as possible. It was felt that, although they were not playing for real money, if the participant was told that the amount of cash they won would be compared to the average individual's winnings then this would motivate them sufficiently to take the task seriously, the cash would become important to them, and they would want to finish the task with as much cash as possible in an attempt to perform better than the average individual.

why not cite previous research with hypothetical reward

*2.1.3.2 Pause task*

In the CP task with forced pause ('Pause' task), the participant performed the same experimental task as in the standard CP task (see above) except that they were forced to wait 5-s between drawing each card from the deck (see Figure 2.3). A 5-s interval was imposed between response feedback (card being shown face-up and cash being added/subtracted accordingly) and the presentation of the next opportunity to respond (the 'Draw' button being available to click on) in the CP task with forced pause. This 5-s interval was accompanied by the text "Please Wait…" displayed on the computer screen below the deck of cards. The 5-s interval between response feedback and the presentation of the next opportunity to respond was imposed in an attempt to interrupt participants' response set and to increase their attention to response feedback on each trial (whether they won cash or lost cash and how much cash they had remaining).

As in the standard CP task (above), the participant was not playing to keep the amount of cash they won on exiting the Pause task. Instead, the participant was informed that although the cash they were playing for was not real money, the amount of cash they finished the game with would be compared to the average individual's winnings and that they should try to finish the game with as much cash as possible. The rationale behind informing the participant of this is explained above in section 2.1.3.1 (Standard task).


*Figure 2.3.* Graphical display of card perseveration task used in the present thesis, illustrating the 5-s forced pause imposed between response feedback and the presentation of the next opportunity to respond (i.e., the 'Draw' button becoming available to click on) on the 'Pause' version of the task.

*2.1.3.3 Dependent measures of card perseveration (CP) task performance*

The two dependent measures associated with response perseveration on the CP task comprise: (1) the number of cards played; and (2) the amount of cash won on exiting the task. These two measures were recorded for each participant on each task. A greater number of cards played and a smaller amount of cash won indicated greater response perseveration on the CP task. Two other dependent measures of interest were yielded from performance on the CP tasks: (1) response latency following wins; and (2) response latency following losses. To assess response latency following wins, response latencies between drawing a winning card and drawing the next card following the win were averaged for each participant on each task. This produced a mean response latency following wins (i.e., the average latency from the onset of the opportunity to draw another card following a winning card until a click on the 'Draw' button) for each participant on each task. To assess response latency following losses, response latencies between drawing a losing card and drawing the next card following the loss were averaged for each participant on each task. This produced a mean response latency following losses (i.e., the average latency from the onset of the opportunity to draw another card following a losing card until a click on the 'Draw' button) for each participant on each task.

### *2.1.4 Slot machine simulations*

Two computerised slot machine simulations were developed, using VB.net, to test the hypotheses: (1) a slot machine simulation with a high percentage payback rate; and (2) a slot machine simulation with a low percentage payback rate.

#### *2.1.4.1 Slot machine simulation with high percentage payback rate*

The parameters of the slot machine simulation with a high percentage payback rate were programmed to 100 trials with a random reinforcement (RR) schedule of 70% (i.e., 70% probability of winning) and a payout magnitude of 2 (2x the amount bet). The on-screen slot machine simulation was a 3D, casino-type, full colour slot machine with flashing lights and appeared to be alongside other slot machines in a casino-type setting (see Figure 2.4). Like a standard casino-type slot machine, the computer simulated slot machine had 3 reels displaying various different symbols and a 'Payline' through the centre of these reels. Below the 3 reels was displayed the participant's total credits left to play with, the amount of credits bet before spinning the reels, and the amount of credits won after placing a bet and spinning the reels. Four buttons appeared in a row at the bottom of the computer simulated slot machine: a 'CASH OUT' button, a 'BET ONE' button, a 'SPIN REELS' button, and a 'BET Max' button.


*Figure 2.4.* Screenshot of computerised slot machine simulation used in the present thesis, showing 'CASH OUT', 'BET ONE', 'SPIN REELS', and 'BET Max' buttons as well as the 'Payline', total credits left to play with ('Total Credits'), the amount of credits bet before spinning the reels ('Bet'), and the amount of credits won after placing a bet and spinning the reels ('Winner Paid') (see text).

The slot machine simulation was presented on a PC computer screen, with the participant seated approximately 50-cm in front of the screen. Each participant was staked with a total of 100 credits to begin playing the slot machine simulation. The participant was instructed to play the slot machine until prompted to click on the 'CASH OUT' button with the goal of cashing out as many credits as possible at the end of play. They were told that the amount of credits they cashed out at the end of play would be compared with the average individual's winnings on the slot machine simulation in an attempt to increase their motivation to perform well. The 'BET ONE' button and the 'BET Max' button appeared lit up at the beginning of each trial while the 'CASH OUT' button and the 'SPIN REELS' button appeared dimmed. If the participant clicked on the 'BET ONE' button then this button would appear dimmed, the 'SPIN REELS' button would appear lit up, and a '1' would be displayed as the amount bet below the reels. If the participant clicked on the 'BET Max' button then this button would appear dimmed, the 'SPIN REELS' button would appear lit up, and a '3' would be displayed as the amount bet below the reels.

Once a bet had been placed and the 'SPIN REELS' button appeared lit up, the participant could click on this button to spin the 3 reels on the slot machine simulation. If, when the reels stopped spinning, 3 identical symbols appeared displayed along the 'Payline' then the participant would win 2x the amount of credits bet before spinning the reels and these credits would be added to the participant's total credits (e.g., 2 credits would be displayed as the amount of credits won had the participant clicked on the 'BET ONE' button before spinning the reels, 6 credits would be displayed as the amount of credits won had the participant clicked on the 'BET Max' button before spinning the reels). However, if the reels stopped spinning and various different symbols appeared displayed along the 'Payline' then the participant would lose the amount of credits bet before spinning the reels (e.g., 1 credit would be deducted from the participant's total credits had the participant clicked on the 'BET ONE' button before spinning the reels, 3 credits would be deducted from the participant's total credits had the participant clicked on the 'BET Max' button before spinning the reels).

After the $100^{th}$ trial, the 'CASH OUT' button appeared lit-up and the other three buttons appeared dimmed. The participant was prompted to cash out their credits after the $100^{th}$ trial by an onscreen message box next to the 'CASH OUT' button containing the text "Click on the Cash Out Button to Continue". At this point in play, clicking on the 'CASH OUT' button was the only option available for the participant as it was no longer possible to place a bet or spin the reels. In an attempt to make the slot machine simulation as engaging and realistic as those found in actual casinos it was designed to produce 'whirring' sounds while the reels were spinning and a 'rewarding' sound when a winning combination of symbols rolled in along the 'Payline'. No sound was produced when a losing combination of symbols rolled in along the 'Payline'.

### *2.1.4.2 Slot machine simulation with low percentage payback rate*

The slot machine simulation with a low percentage payback rate was exactly the same as the slot machine simulation with a high percentage payback rate (see above) except that it had a random reinforcement (RR) schedule of 30% (i.e., 30% probability of winning). As in the slot machine simulation with a high percentage payback rate (above), the participant was told prior to playing the slot machine simulation with a low percentage payback rate that the amount of credits they cashed out at the end of play would be compared with the average individual's winnings on the slot machine simulation in an attempt to increase their motivation to perform well.

### *2.1.4.3 Dependent measures of slot machine simulation performance*

There were four dependent measures of interest yielded from slot machine simulation performance: (1) total credits bet; (2) response latency; (3) response latency following wins; and (4) response latency following losses. To assess total number of credits bet, the number of credits bet on each trial (i.e., 1 credit if the 'BET ONE' button was clicked on, 3 credits if the 'BET Max' button was clicked on) was summed across the 100 trials for each participant on each slot machine simulation. To assess response latency, response latencies between the reels of the slot machine simulation stopping and the next bet placed were averaged for each participant on each slot machine simulation. This produced a mean response latency (i.e., the average latency from the onset of the reels of the slot machine simulation stopping until a click on the 'SPIN REELS' button) for each participant on each slot machine simulation.

To assess response latency following wins, response latencies between the reels of the slot machine simulation stopping on a winning combination of symbols and the next bet placed were averaged for each participant on each slot machine simulation. This produced a mean response latency following wins (i.e., the average latency from the onset of the reels of the slot machine simulation stopping on a winning combination of symbols until a click on the 'SPIN REELS' button) for each participant on each slot machine simulation. To assess response latency following losses, response latencies between the reels of the slot machine simulation stopping on a losing combination of symbols and the next bet placed were averaged for each participant on each slot machine simulation. This produced a mean response latency following losses (i.e., the average latency from the onset of the reels of the slot machine simulation stopping on a losing combination of symbols until a click on the 'SPIN REELS' button) for each participant on each slot machine simulation.

## 2.2 Psychometric measures of personality

### *2.2.1 BIS/BAS Scales*

The BIS/BAS Scales (Carver & White, 1994) consist of 24 self-report items, each measured on a 4-point response scale, with 1 indicating strong agreement and 4 indicating strong disagreement. The BIS subscale is composed of seven items, designed to measure reactions to anticipated punishment. The BAS is made up of three separate subscales: Drive (four items, e.g., 'I go out of my way to get things I want'), Fun-Seeking (four items, e.g., 'I'm always willing to try something new if I think it will be fun'), and Reward Responsiveness (five items, e.g., 'When I am doing well at something I love to keep at it'). Items 1, 6, 11, and 17 are filler items. It is a well-established personality questionnaire that has been widely employed in previous research and is known to be valid and reliable (e.g., Ross, Millis, Bonebright, & Bailley, 2002; Cronbach's alpha in the present thesis was .74, .80, .69 and .74 for BAS Drive, BAS Fun-Seeking, BAS Reward Responsiveness and BIS, respectively).

### *2.2.2 Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ)*

The SPSRQ (Torrubia et al., 1995) consists of 48 self-report items, each measured on a Yes-No response scale, with Yes indicating agreement and No indicating disagreement. It is designed to measure sensitivity to the BIS and the BAS and comprises two subscales: (1) Sensitivity to

Punishment (SP) items measure the BIS (24 items); and (2) Sensitivity to Reward (SR) items measure the BAS (24 items). SP items describe reactivity in situations with a predominance of punishment (e.g., 'Do you often refrain from doing something because you are afraid of it being illegal?'), while SR items describe reactivity in situations that are predominantly rewarding (e.g., 'Does the good prospect of obtaining money motivate you strongly to do some things?'). There are no filler items. It is a well-established personality questionnaire that has been widely employed in previous research and is known to be valid and reliable (e.g., O'Connor, Colder, & Hawk, 2004; Cronbach's alpha in the present thesis was .87 and .72 for SP and SR, respectively).

### *2.2.3 Revised Eysenck Personality Questionnaire short scale (EPQ-RS)*

The EPQ-RS (Eysenck, Eysenck, & Barrett, 1985) consists of 48 self-report items, each measured on a Yes-No response scale, with Yes indicating agreement and No indicating disagreement. It is designed to measure three dimensions of personality as well as the tendency to be untruthful. It is composed of four separate subscales: EPQ-P (Psychoticism; 12 items, e.g., 'Do you take much notice of what people think?'), EPQ-E (Extraversion; 12 items, e.g., 'Are you a talkative person?'), EPQ-N (Neuroticism; 12 items, e.g., 'Does your mood often go up and down?'), and EPQ-L (Lie; 12 items, e.g., 'If you say you will do something, do you always keep your promise no matter how inconvenient it might be?'). There are no filler items. The EPQ is a well-established personality questionnaire that has been used in hundreds of previous studies and the revised short scale version used in the present study is known to be valid and reliable (e.g., Francis & Pearson, 1988; Cronbach's alpha in the present thesis was .46, .86, .83 and .67 for Psychoticism, Extraversion, Neuroticism and Lie, respectively; the Psychoticism scale was not central to the hypotheses of the present thesis, so its low reliability was not anticipated to be a problem).

*2.2.4 Spielberger State-Trait Anxiety Inventory (STAI) Y2 (trait) scale*

The STAI Y2 scale (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) consists of 20 self-report items designed to measure trait anxiety. Respondents are instructed to rate the extent to which they generally feel the same as 20 statements such as 'I feel nervous and restless' or 'I worry too much over something that really doesn't matter', with reference to a 4-point rating scale ranging from 1 (almost never) to 4 (almost always). It is a well-established measure of anxiety that has been used in hundreds of previous studies and is known to be valid and reliable (e.g., Barnes, Harp, & Jung, 2002; its Cronbach's alpha in the present thesis was .93).

*2.2.5 Fear Survey Schedule (FSS)*

The long form version of the FSS (Wolpe & Lang, 1977) used in the present study consists of 108 self-report items designed to assess fear. Respondents are instructed to rate the extent to which they would be disturbed by each of 108 items representing specific aversive stimuli such as 'sudden noises', 'bats' or 'speaking in public', with reference to a 4-point rating scale ranging from 0 (not at all) to 4 (very much). It has been used in scores of previous studies that indicate it to be the most valid and reliable measure of fear available (e.g., Oei, Cavallo, & Evans, 1987; its Cronbach's alpha in the present thesis was .97).

*2.2.6 Positive and Negative Affect Schedule (PANAS)*

The PANAS (Watson, Clark, & Tellegen, 1988) consists of 20 self-report items: 10 of which are designed to measure positive affect; 10 of which are designed to measure negative affect. The items comprising these two mood scales (positive and negative affect) are single-word descriptors of different feelings and emotions such as 'excited', 'strong' or 'enthusiastic' for the positive affect scale and 'distressed', 'afraid' or 'irritable' for the negative affect scale. Respondents are instructed to rate the extent to which they have experienced each particular emotion within a specified time period, with reference to a 5-point rating scale ranging from 1 (very slightly or not at all) to 5 (extremely). A number of different time periods can be used with the PANAS depending on the aim of investigation but for the purpose of the present study, the time period adopted was 'right now, that is, at the present moment'. It is a well-established measure of affect that has been used in scores of previous studies and is known to be valid and reliable (e.g., Crawford & Henry, 2004; Cronbach's alpha in the present thesis was .82 and .88 for positive affect and negative affect, respectively).

*2.2.7 South Oaks Gambling Screen (SOGS)*

The SOGS (Lesieur & Blume, 1987) consists of 35 self-report items: 20 of which are designed to measure past gambling behaviours; 15 of which are filler items. The 20 items of interest comprise questions relevant to the *DSM-IV* (APA, 1994) criteria for pathological gambling such as 'Did you ever gamble more than you intended?' or 'Have you ever lost time from work (or school) due to gambling?' measured, for the most part, on a Yes-No response scale, with Yes indicating agreement (scored 1) and No indicating disagreement (scored 0). The total score can range from 0 to 20. It is a sensitive measure of gambling severity and the most widely used diagnostic tool for identifying pathological gamblers (score of 5 or greater) and problem gamblers (score of 3 or 4). It has demonstrated satisfactory validity and reliability both in gambling treatment samples and in the general population (e.g., Stinchfield, 2002).

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# Chapter 3

# Experiments 1, 2 and 3:

# Development of the Stop-signal Tasks

The stop-signal task used to investigate inhibitory control in the bulk of previous studies (including all of the studies mentioned in chapter 1, section 1.1.1) had no specific motivational stimuli. Although it could be argued that the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), there is still a lack of any specific motivational stimuli on the standard stop-signal task based on Logan's original.

Previous studies attempting to investigate the effects of reward and punishment contingencies on task performance have been very few to date, and those that do exist have been limited in certain ways (as highlighted in chapter 1, section 1.1.1.1). The idea that performance on the stop-signal task can be modified using specific rewarding/punishing stimuli could provide valuable information on how to moderate and explain inhibitory control in other situations (e.g., gambling behaviour).

The purpose of the present study was to: (a) develop stop-signal tasks with different response contingencies in order to investigate their effects on inhibitory control and task performance; and (b) evaluate the hypothesis that inhibitory control on the stop-signal task could be modified using different response contingencies.

## 3.1 Experiment 1

### *3.1.1 Aims and experimental predictions*

### 3.1.1.1 Aims

The aim of Experiment 1 was to investigate inhibitory control and performance on the stop-signal task in the presence of different response contingencies. Four computer based stop-signal tasks were designed using E-Prime (version 1.2) software. These tasks were designed since no previous research has used tasks suitable for testing the dependent variables of interest here. One task was designed to be a standard stop-signal task, serving as a baseline motor inhibition task without specific motivational stimuli (the Baseline task); the second task was designed to create an avoidance situation in which the participant performed the standard task but was punished by losing points depending on their performance (the Punishment task); the third task was designed to create an approach situation in which the participant performed the standard task but was rewarded by winning points depending on their performance (the Reward task); and the fourth task was designed to create an approach-avoidance conflict situation in which the participant performed the standard task but was rewarded and punished, by winning and losing points, depending on their performance (the Conflict task). No previous research has investigated the influence of these four stop-signal task contingencies on inhibitory control and task performance within-subjects.

### 3.1.1.2 Experimental predictions

A number of predictions were generated. First, the presence of specific punishing stimuli, in the form of points lost for errors made on go-trials and for lack of inhibition on stop-trials, on the Punishment stop-signal task should result in participants performing the task with greater caution. This would prompt the prediction that an increased care in performance should result in stronger inhibitory control on the Punishment stop-signal task compared to on the Baseline, Reward, and Conflict tasks. Second, the presence of specific rewarding stimuli, in the form of points won for speeded responses on go-trials, on the Reward stop-signal task should result in participants performing the task with an increased motivation on go-trials and, consequently, with less caution. This would prompt the prediction that a decreased care in performance should result in weaker inhibitory control on the

Reward stop-signal task compared to on the Baseline, Punishment, and Conflict tasks. Finally, the presence of both specific rewarding and punishing stimuli, in the form of points won for speeded responses on go-trials and points lost for errors made on go-trials and for lack of inhibition on stop-trials, respectively, on the Conflict stop-signal task should result in participants performing the task with greater motivation on go-trials combined with greater care not to make errors. This would prompt the prediction that an increased motivation on go-trials combined with an increased care not to make errors should result in: similar inhibitory control on the Conflict stop-signal task compared to on the Baseline task; weaker inhibitory control on the Conflict stop-signal task compared to on the Punishment task; and stronger inhibitory control on the Conflict stop-signal task compared to on the Reward task.

### *3.1.2 Method*

#### *3.1.2.1 Participants*

Ten undergraduate students (3 males, 7 females), studying psychology at Swansea University, participated. Participants' ages ranged between 18 and 23 years (mean = 19.80, S.D. = 1.40). They were recruited by means of volunteer or self-selected sampling methods using a subject pool credit website, and gave their written informed consent to take part in the experiment after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded course credits for their participation.

#### *3.1.2.2 Materials and design*

##### *3.1.2.2.1 Stop-signal tasks*

The Baseline stop-signal task was the same as that described in chapter 2, section 2.1.1.1. The Punishment stop-signal task in the present experiment was the same as described in chapter 2, section

2.1.1.2, except for the following difference: the computer screen did not appear red and display the text "POOR! You lose 10 points!" in the centre of the screen for 1000-ms accompanied by an unpleasant "buzz" sound each time participants failed to inhibit a response on stop-trials, responded with the wrong key, or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle). Instead, in the Punishment task in the present experiment, each time participants failed to inhibit a response on stop-trials, responded with the wrong key, or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle) the text '-5' was displayed in the centre of the computer screen for 1000-ms before the next trial began.

The Reward stop-signal task in the present experiment was the same as described in chapter 2, section 2.1.1.3, except for the following difference: the computer screen did not appear blue and display the text "GOOD! You win 10 points!" in the centre of the screen for 1000-ms accompanied by a pleasant "ring" sound each time participants responded, with the correct key, to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline task). Instead, in the Reward task in the present experiment, each time participants responded, with the correct key, to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline task) the text '+5' was displayed in the centre of the computer screen for 1000-ms before the next trial began.

The Conflict stop-signal task in the present experiment was the same as described in chapter 2, section 2.1.1.4, except for the following differences: the computer screen did not appear blue and display the text "GOOD! You win 10 points!" in the centre of the screen for 1000-ms accompanied by a pleasant "ring" sound each time participants responded, with the correct key, to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline task) and the computer screen did not appear red and display the text "POOR! You lose 10 points!" in the centre of the screen for 1000-ms accompanied by an unpleasant "buzz" sound each time participants failed to inhibit a response on stop-trials, responded with the wrong key, or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle). Instead, in the Conflict task in the present experiment, each time participants responded, with the correct key, to go-task stimuli on go-trials (i.e., letters without the green circle) faster than their baseline mean reaction time (MRT) on correct response go-trials (obtained from their performance on the Baseline task) the text '+5' was displayed in the centre of the computer screen for 1000-ms before the next trial began and each time participants failed to inhibit a response on stop-trials, responded with the wrong key, or failed to respond to go-task stimuli on go-trials (i.e., letters without the green circle) the text '-5' was displayed in the centre of the computer screen for 1000-ms before the next trial began.

The written Baseline, Punishment, Reward, and Conflict task instructions given to participants are shown in full in Appendices A, B, C, and D, respectively.

*3.1.2.2.2 Stop-signal task order*

In order to provide a direct measure of baseline motor-inhibition, avoiding any possible differential sequential effects in personality due to the other three conditions, each participant was tested on the Baseline task first. In an attempt to minimize any possible confounding task order effects, the order of the Punishment task and the Reward task was counterbalanced across participants. Half of the participants were tested on the Punishment task before the Reward task and half of the participants were tested on the Reward task before the Punishment task. It seemed a logical progression to have each participant perform the Conflict task as the final task to provide a measure of motor-inhibition in an approach-avoidance conflict situation since the Conflict task has all of the characteristics of the previous three tasks combined.

*3.1.2.3 Procedure*

On arrival at the laboratory the participant was seated and instructed to read the information sheet (the details of which are outlined below) and to ask for a consent form when finished if they wished to continue. The information sheet informed the participant that the present study involved performing a series of tasks presented on a computer. It also explained how written instructions of how to perform each computer task would be provided. The information sheet assured the participant that they were free to withdraw from the study at any point without penalty, that they could request a break at any time, that all results would be anonymised and that it would not be possible to identify individual participant's data. If the participant wished to continue having read the information sheet they were instructed to complete the written consent form. The completed consent form was kept separately from all other data in order to ensure the confidentiality and anonymity of the participant's results.

Having obtained informed consent, the four computer based stop-signal tasks described in the materials and design section above (section 3.1.2.2) were administered to the participant. The order in which the four stop-signal tasks were administered is described in the materials and design section above (section 3.1.2.2). The participant was instructed to follow the written instructions provided at the beginning of each computer task. They were debriefed on completion of the final stop-signal task (the Conflict task) and thanked for their participation. The participant was again assured that all the information they provided would remain confidential to the study and that the information they provided would be used to investigate inhibitory control on the stop-signal task in the presence of reward and punishment. The data collected and saved from each of the four stop-signal tasks for each of the ten participants had to be individually analysed and recorded in spreadsheets.

*3.1.2.4 Dependent measures and data analyses of stop-signal task performance*

*3.1.2.4.1 Dependent measures of stop-signal task performance*

See chapter 2, section 2.1.1.5, for detailed descriptions of dependent measures of response inhibition (probability of inhibition on stop-trials and stop-signal reaction time), response execution (go-trial reaction time and go-trial response accuracy) and methods for assessing these dependent measures for each participant on each task.

*3.1.2.4.2 Data analyses of stop-signal task performance*

*3.1.2.4.2.1 Order effects*

Effects of the counterbalancing variable Order on the four criterion measures of stop-signal task performance across Task were analysed by separate two-way mixed analyses of variance (ANOVA) with Order (Punishment task before Reward task or Reward task before Punishment task) as the between-subjects factor. Adjustment was made for four covariates (one in each ANOVA): baseline probability of inhibition on stop-trials, baseline stop-signal reaction time (SSRT), baseline mean reaction time (MRT) on go-trials and baseline go-trial response accuracy. Baseline task performance measures were included as covariates to assess the effect of Order on task performance measures after adjusting for initial differences in stop-signal task performance. The within-subjects factor was the three Tasks performed after the Baseline stop-signal task: the Punishment, Reward, and Conflict tasks. $N = 5$ for both Orders. There were no univariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

There was no significant main effect of Order, $F(1, 7) = 0.01$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 1.54$, $p > .05$, for probability of inhibition on stop-trials. There was no significant main effect of Order, $F(1, 7) = 1.06$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 0.90$, $p > .05$, for SSRT. No significant main effect of Order, $F(1, 7) = 0.67$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 1.35$, $p > .05$, was revealed for MRT on go-trials. There was no significant main effect of Order, $F(1, 7) = 0.40$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 1.81$, $p > .05$, for go-trial response accuracy. Since none of the main effects or interactions involving Order was significant, data were collapsed for subsequent analyses.

*3.1.2.4.2.2 Task effects*

Task effects on the two criterion measures of response inhibition (probability of inhibition on stop-trials and SSRT) and on the two criterion measures of response execution (MRT on go-trials and go-trial response accuracy) were analysed by separate doubly-multivariate analyses of variance (MANOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor treated multivariately. Specific hypotheses concerning task differences in response inhibition between individual tasks were tested using simple within-subjects contrasts.

*3.1.2.4.2.3 Effects of stop-signal delay on probability of inhibition*

Effects of stop-signal delay on probability of inhibition on stop-trials were analysed by separate one-way repeated measure analysis of variance (ANOVA) with Delay (50, 150, 250 and 350-ms) as the within-subjects factor. Polynomial within-subjects contrasts were used to test the hypotheses that probability of inhibition should decrease in a linear fashion across the four stop-signal delays, from 50 to 350-ms, on each stop-signal task.

### *3.1.3 Results*

There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

#### *3.1.3.1 Task effects on stop-signal task performance*

##### *3.1.3.1.1 Response inhibition*

Doubly-MANOVA revealed significant multivariate effects for the main effect of Task on the two measures of response inhibition (probability of inhibition on stop-trials and SSRT), $F(6, 4) = 7.40$, $p < .05$; Wilks' Lambda = .08. This indicates that, consistent with prediction, mean measures of response inhibition differed across the four tasks with different response contingencies. Means and standard deviations of stop-signal task performance measures across the four tasks are shown in Table 3.1.

###### *3.1.3.1.1.1 Probability of inhibition on stop-trials*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Punishment task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 8.65$, $p < .05$, the Reward task, $F(1, 9) = 10.60$, $p < .05$, and on the Conflict task, $F(1, 9) = 11.01$, $p < .01$. Mean probability of inhibition on stop-trials across the four stop-signal tasks is shown in Figure 3.1. Examination of Figure 3.1 indicates that, as predicted, probability of inhibition on stop-trials was higher (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, higher on the Punishment task than on the Reward task and higher on the Punishment task than on the Conflict task.

Table 3.1

*Mean and Standard Deviation of Stop-signal Task Performance Measures across the Four Tasks*

| Measure | Stop-signal Task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | Punishment | | Reward | | Conflict | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *P* (Inhibition) | 0.63 | 0.17 | 0.73 | 0.15 | 0.58 | 0.16 | 0.60 | 0.14 |
| SSRT (msec) | 289 | 48.72 | 234 | 44.96 | 254 | 38.01 | 257 | 61.07 |
| MRT (msec) | 537 | 58.94 | 530 | 54.59 | 481 | 58.02 | 488 | 57.58 |
| No. of errors | 6.90 | 4.61 | 5.20 | 5.41 | 7.30 | 4.52 | 7.90 | 6.61 |

*Note.* n = 10; *P* (Inhibition) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; No. of errors = number of response errors made on go-trials.

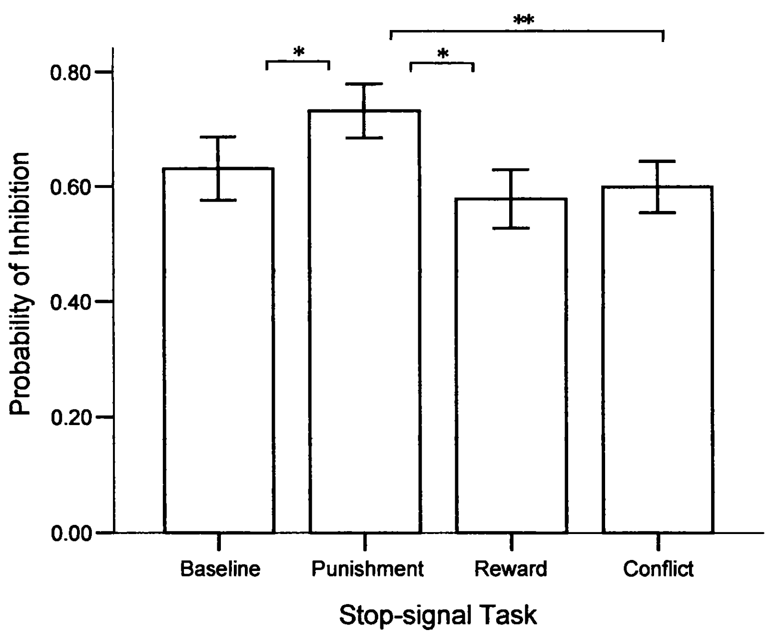


*Figure 3.1.* Mean probability of inhibition on stop-trials ( ± 1 SE) for Baseline (n = 10), Punishment (n = 10), Reward (n = 10), and Conflict (n = 10) stop-signal tasks.

**p* < .05. ***p* < .01.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed, contrary to prediction, no significant mean difference between probability of inhibition on stop-trials on the Reward task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 1.60, p > .05$, or on the Conflict task, $F(1, 9) = 0.38, p > .05$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between probability of inhibition on stop-trials on the Conflict task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 0.98, p > .05$.

*3.1.3.1.1.2 Stop-signal reaction time (SSRT)*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed a significant mean difference between SSRT on the Punishment task and SSRT on the Baseline task, $F(1, 9) = 27.68, p < .01$. Mean SSRT across the four stop-signal tasks is shown in Figure 3.2. Examination of Figure 3.2 indicates that, as predicted, SSRT was faster (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task. Contrary to prediction, there was no significant mean difference between SSRT on the Punishment task and SSRT on the Reward task, $F(1, 9) = 1.60, p > .05$, or on the Conflict task, $F(1, 9) = 1.76, p > .05$.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed a significant mean difference between SSRT on the Reward task and SSRT on the Baseline task, $F(1, 9) = 6.14, p < .05$. Examination of Figure 3.2 indicates that, contrary to prediction, SSRT was faster (i.e., inhibitory control was stronger) on the Reward task than on the Baseline task. Also contrary to prediction, there was no significant mean difference between SSRT on the Reward task and SSRT on the Conflict task, $F(1, 9) = 0.07, p > .05$.

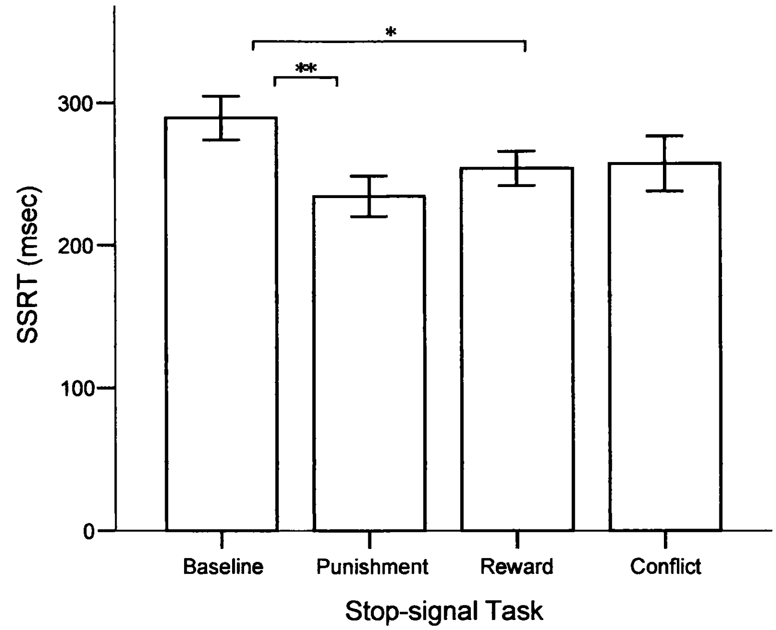


*Figure 3.2.* Mean stop-signal reaction time (SSRT) ( ± 1 SE) for Baseline (n = 10), Punishment (n = 10), Reward (n = 10), and Conflict (n = 10) stop-signal tasks.

*$p < .05$. **$p < .01$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between SSRT on the Conflict task and SSRT on the Baseline task, $F(1, 9) = 4.04, p > .05$.

*3.1.3.1.2 Response execution*

Doubly-MANOVA revealed no significant multivariate effects for the main effect of Task on the two measures of response execution (MRT on go-trials and go-trial response accuracy), $F(6, 4) = 3.38$, $p > .05$; Wilks' Lambda = .17.

*3.1.3.2 Effects of stop-signal delay on probability of inhibition*

ANOVA revealed a significant main effect of Delay on probability of inhibition on stop-trials on the Baseline, $F(3, 27) = 44.53, p < .01$, Punishment (Greenhouse-Geisser correction),

$F(1.93, 17.33) = 46.47$, $p < .01$, Reward (Greenhouse-Geisser correction), $F(1.60, 14.38) = 75.92$, $p < .01$, and Conflict, $F(3, 27) = 59.04$, $p < .01$, tasks. Figure 3.3 plots mean probability of inhibition at each stop-signal delay on each of the four stop-signal tasks. Figure 3.3 indicates that, as expected, probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay. This function was evident on all four tasks and polynomial within-subjects contrasts revealed these functions to be significant linear trends on the Baseline, $F(1, 9) = 108.44$, $p < .01$, Punishment, $F(1, 9) = 84.13$, $p < .01$, Reward, $F(1, 9) = 315.95$, $p < .01$, and Conflict, $F(1, 9) = 234.94$, $p < .01$, tasks. This indicates that, as predicted, probability of inhibition decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each on the four stop-signal tasks.

### *3.1.4 Discussion*

The results obtained in the present experiment provided support for the idea that inhibitory control on the stop-signal task can be modified using different response contingencies. Significant evidence was found to support the prediction that inhibitory control should differ across the four stop-signal tasks with different response contingencies. However, specific predictions concerning differences in inhibitory control between individual tasks received mixed support. It was predicted that, due to an increased care in performance resulting from the presence of specific punishing stimuli (in the form of points lost for errors made on go-trials and for lack of inhibition on stop-trials) on the Punishment stop-signal task, inhibitory control should be stronger on this task compared to on the Baseline, Reward, and Conflict tasks. Participants stopped for a greater proportion of stop-signals (i.e., probability of inhibition on stop-trials was higher) and displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Punishment task compared to on the Baseline task. Together, these findings provide evidence in support of the prediction that inhibitory control should be stronger on the Punishment stop-signal task compared to on the Baseline task. Participants stopped for a greater proportion of stop-signals (i.e., probability of inhibition on stop-trials was higher) on the Punishment task compared to on the Reward task and compared to on the Conflict task. Thus, based on this measure of response inhibition, these findings support predictions that inhibitory control should be stronger on the Punishment stop-signal task compared to on the Reward task and compared to on the Conflict task. However, participants showed no significant change in estimated time to inhibit a response (i.e., SSRT did not differ significantly) on the Punishment task compared to on the Reward task or compared to on the Conflict task. Although not significant, the mean differences in SSRT between these tasks were in the predicted direction so perhaps with a larger sample size or with slight modifications to stop-signal task response contingencies (i.e., increased potency of specific punishing/rewarding stimuli) these mean differences might become significant.

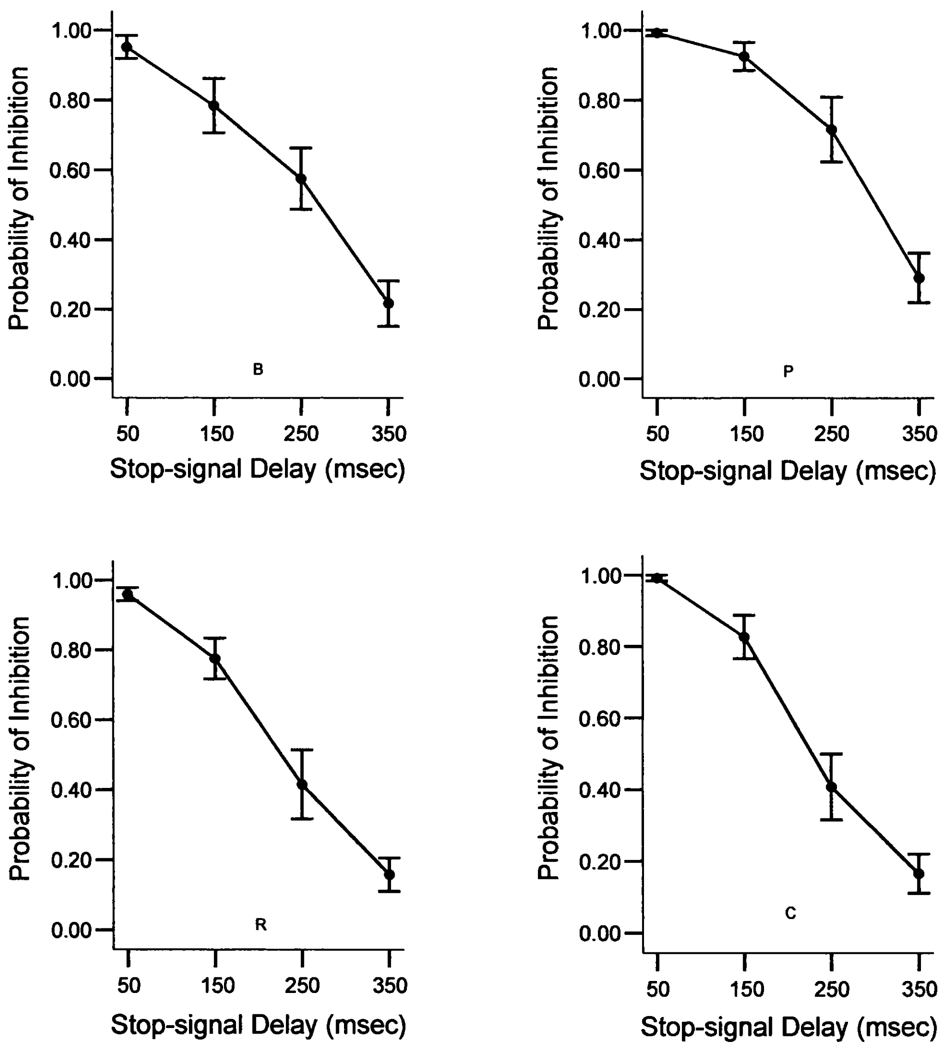


*Figure 3.3.* Mean probability of inhibition at each stop-signal delay ( ± 1 SE) on the Baseline (panel B), Punishment (panel P), Reward (panel R) and Conflict (panel C) stop-signal tasks.

It was also predicted that, due to a decreased care in performance resulting from the presence of specific rewarding stimuli (in the form of points won for speeded responses on go-trials) on the Reward stop-signal task, inhibitory control should be weaker on this task compared to on the Baseline, Punishment, and Conflict tasks. Differences in inhibitory control on the Reward task compared to on the Punishment task have been discussed above. Surprisingly, participants displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Reward stop-signal task compared to on the Baseline task. This suggests that, based on this measure of response inhibition, inhibitory control was actually stronger on the Reward task than it was on the Baseline task, contrary to prediction. However, the lack of a significant mean difference in participants' probability of inhibition on stop-trials between these two tasks does not support this suggestion. In fact, participants' mean probability of inhibition on stop-trials was slightly lower on the Reward task than it was on the Baseline task indicating a trend towards the opposite (and predicted) suggestion (i.e., that inhibitory control should be weaker on the Reward stop-signal task compared to on the Baseline task). Perhaps if the potency of the specific rewarding stimuli present on the Reward task were to be strengthened in some way then this trend toward a lower probability of inhibition on the Reward task compared to on the Baseline task might become a significant difference. This lack of inhibition on stop-trials might then, in turn, be reflected in a slower estimated time to inhibit a response (i.e., slower SSRT) in the presence of greater rewarding stimuli on the Reward task compared to on the Baseline task. No significant evidence was obtained in the present experiment to support the prediction that inhibitory control should be weaker on the Reward stop-signal task compared to on the Conflict task. Again, although not significant, mean differences in measures of response inhibition on the Reward task compared to on the Conflict task were in the predicted direction so perhaps if slight modifications were to be made to task response contingencies (i.e., strengthened potency of punishing/rewarding stimuli) then these mean differences might become significant.

Finally, it was predicted that, due to an increased motivation on go-trials combined with an increased care not to make errors resulting from the presence of both specific rewarding and punishing stimuli, inhibitory control should be: similar on the Conflict stop-signal task compared to on the Baseline task; weaker on the Conflict stop-signal task compared to on the Punishment task; and stronger on the Conflict stop-signal task compared to on the Reward task. Differences in inhibitory control on the Conflict task compared to on the Punishment and Reward tasks have been discussed above. Inhibitory control was found to be similar on the Conflict task compared to on the Baseline task, consistent with prediction.

The presence of different response contingencies had no effect on participants' ability to execute responses on the stop-signal task, in terms of their speed and accuracy on go-trials. This indicates that the specific motivational stimuli present on the stop-signal tasks in the present experiment impaired the ability to inhibit behavioural responses without affecting the ability to execute responses.

*3.1.4.1 Possible reasons for mixed support of predictions*

Some of the predictions were not supported by significant results, as mentioned above, indicating that either the predictions made were inaccurate or that the tasks were not designed as well as they could have been. The fact that the majority of non-significant mean differences found between measures of response inhibition on the stop-signal tasks were in the right direction to be in line with prediction lends support to the notion that the tasks used in the present experiment were not designed quite as well as they could have been rather than to the possibility that the predictions made were inaccurate. It is possible that, in the case of the non-significant mean differences found, the specific rewarding/punishing stimuli present on the Punishment, Reward and Conflict tasks was simply not quite potent enough to effect participants' inhibitory control across the tasks in the expected manner. In order to strengthen the potency of the specific motivational stimuli present on the Punishment, Reward and Conflict tasks, these tasks could be modified in certain ways. For example, colour and sound could be introduced as accompaniments to the rewarding/punishing stimuli of points won/lost on these stop-signal tasks as this might help to intensify the potency of the specific motivational stimuli. The specific rewarding stimuli experienced by participants on the Reward and Conflict tasks could be made more potent by modifying these tasks so that, instead of "+5" appearing in the centre of the computer screen (as in the present experiment), the computer screen could appear blue in colour and display the text "GOOD! You win 10 points!" accompanied by a pleasant "ring" sound. The specific punishing stimuli experienced by participants on the Punishment and Conflict tasks could be made more potent by modifying these tasks so that, instead of "-5" appearing in the centre of the computer screen (as in the present experiment), the computer screen could appear red in colour and display the text "POOR! You lose 10 points!" accompanied by an unpleasant "buzz" sound. The addition of potentially rewarding/punishing stimuli in the form of colour (blue for reward, red for punishment), sound (pleasant ring for reward, unpleasant buzz for punishment) and text ("GOOD" and "win" for reward, "POOR" and "lose" for punishment) should strengthen the potency of the different response contingencies and could, therefore, potentially result in the stop-signal tasks being performed more in accordance with prediction.

In addition to the potential modifications to stop-signal tasks themselves (discussed above), the written instructions given to participants before the Punishment, Reward and Conflict tasks (see Appendices B, C, and D respectively) could be modified since it is possible that they did not emphasise enough the importance of the rewarding/punishing points available on these tasks. Greater emphasis on the importance of task performance in terms of winning/losing points within the written instructions could potentially be an effective way of increasing participants' interest in the specific motivational stimuli and, thus, could potentially strengthen the potency of the specific rewarding/punishing stimuli present on these tasks.

*3.1.4.2 Validity of stop-signal task design*

The choice reaction time task designed for the Baseline task was similar to that used in Avila and Parcet's (2001) study. MRT on go-trials on the Baseline task (537-ms) was faster than MRT on go-trials on the stop-signal task used in Avila and Parcet's study (744-ms), indicating that the go-task was easier on the standard task in the present experiment. The four fixed stop-signal delays (50, 150, 250 and 350-ms) used in the stop-task component of each of the four tasks in the present experiment were the same as those used by Fillmore et al. (2001, 2002) and Fillmore and Rush (2002). Consistent with their findings, probability of inhibition was found to decrease in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each of the four tasks in the present experiment. Figure 3.3 shows the negative slope functions that relate probability of inhibition to the stop-signal delays on each of the four tasks. The presence of these slopes not only provides verification of successful employment of appropriate delays but also that participants understood task requirements and correctly followed instructions (see chapter 1, section 1.1, for further explanation). The negative slopes obtained demonstrate that response inhibition was under some degree of stimulus control of the stop-signals on all four tasks.

## 3.2 Experiment 2

### *3.2.1 Aims and experimental predictions*

Experiment 2 was conducted with the same aim and predictions as in Experiment 1 using modified versions of the Punishment, Reward and Conflict stop-signal tasks and written task instructions. It was suspected that the specific motivational stimuli present on the Punishment, Reward and Conflict tasks in Experiment 1 was not as effective as it could have been and that by strengthening the potency of this motivational stimuli in some way, the effects on inhibitory control and performance on the stop-signal task should become more in line with prediction.

### 3.2.2 Method

#### 3.2.2.1 Participants

Ten undergraduate students (4 males, 6 females), studying psychology at the Swansea University, participated. Participants' ages ranged between 18 and 24 years (mean = 20.50, S.D. = 2.32). They were recruited by means of volunteer or self-selected sampling methods using a subject pool credit website, and gave their written informed consent to take part in the experiment after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded course credits for their participation.

#### 3.2.2.2 Materials and design

The Baseline stop-signal task was the same as that used in Experiment 1. Modified versions of the Punishment, Reward, and Conflict stop-signal tasks used in Experiment 1 were used in the present experiment. See chapter 2, section 2.1.1, for a detailed description of each of the four tasks used in the present experiment. The written Baseline task instructions given to participants were the same as those given to participants in Experiment 1 and are shown in full in Appendix A. The written Punishment, Reward, and Conflict task instructions given to participants were modified versions of those given to participants in Experiment 1 and are shown in full in Appendices E, F, and G, respectively. The order of task administration was the same as in Experiment 1 (see section 3.1.2.2.2).

#### 3.2.2.3 Procedure

The procedure followed was the same as detailed in section 3.1.2.3 in Experiment 1 except that the stop-signal tasks administered to participants in the present experiment were those described in the materials and design section above (section 3.2.2.2) rather than those described in section 3.1.2.2.

*3.2.2.4 Dependent measures and data analyses of stop-signal task performance*

*3.2.2.4.1 Dependent measures of stop-signal task performance*

Dependent measures of stop-signal task performance in the present experiment were identical to those in Experiment 1 (see section 3.1.2.4.1).

*3.2.2.4.2 Data analyses of stop-signal task performance*

*3.2.2.4.2.1 Order effects*

Effects of the counterbalancing variable Order on the four criterion measures of stop-signal task performance across Task were analysed by separate two-way mixed analyses of variance (ANOVA) with Order (Punishment task before Reward task or Reward task before Punishment task) as the between-subjects factor. Adjustment was made for four covariates (one in each ANOVA): baseline probability of inhibition on stop-trials, baseline SSRT, baseline MRT on go-trials and baseline go-trial response accuracy. Baseline task performance measures were included as covariates to assess the effect of Order on task performance measures after adjusting for initial differences in stop-signal task performance. The within-subjects factor was the three Tasks performed after the Baseline stop-signal task: the Punishment, Reward, and Conflict tasks. $N = 5$ for both Orders. There were no univariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

There was no significant main effect of Order, $F(1, 7) = 0.92$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 1.63$, $p > .05$, for probability of inhibition on stop-trials. There was no significant main effect of Order, $F(1, 7) = 3.22$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 0.99$, $p > .05$, for SSRT. No significant main effect of Order, $F(1, 7) = 1.41$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 0.96$, $p > .05$, was revealed for MRT on go-trials. There was no significant main effect of Order, $F(1, 7) = 1.63$, $p > .05$, and no significant interaction between Order and Task, $F(2, 14) = 0.22$, $p > .05$, for go-trial response accuracy. Since none of the main effects or interactions involving Order was significant, data were collapsed for subsequent analyses.

*3.2.2.4.2.2 Task effects*

Task effects on the two criterion measures of response inhibition (probability of inhibition on stop-trials and SSRT) and on the two criterion measures of response execution (MRT on go-trials and go-trial response accuracy) were analysed by separate doubly-multivariate analyses of variance (MANOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor treated multivariately. Specific hypotheses concerning task differences in response inhibition between individual tasks were tested using simple within-subjects contrasts. Task differences in response execution were investigated by univariate ANOVA and pairwise comparisons, adjusted according to the Bonferroni method, generated from the omnibus doubly-MANOVA.

*3.2.2.4.2.3 Effects of stop-signal delay on probability of inhibition*

Effects of stop-signal delay on probability of inhibition on stop-trials were analysed by separate one-way repeated measure analysis of variance (ANOVA) with Delay (50, 150, 250 and 350-ms) as the within-subjects factor. Polynomial within-subjects contrasts were used to test the hypotheses that probability of inhibition should decrease in a linear fashion across the four stop-signal delays, from 50 to 350-ms, on each stop-signal task.

### 3.2.3 Results

There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

#### 3.2.3.1 Task effects on stop-signal task performance

##### 3.2.3.1.1 Response inhibition

Doubly-MANOVA revealed significant multivariate effects for the main effect of Task on the two measures of response inhibition (probability of inhibition on stop-trials and SSRT), $F(6, 4) = 29.40$, $p < .01$; Wilks' Lambda = .02. This indicates that, consistent with prediction, mean measures of response inhibition differed across the four tasks with different response contingencies. Means and standard deviations of stop-signal task performance measures across the four tasks are shown in Table 3.2.

###### 3.2.3.1.1.1 Probability of inhibition on stop-trials

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Punishment task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 8.42$, $p < .05$, the Reward task, $F(1, 9) = 92.78$, $p < .01$, and on the Conflict task, $F(1, 9) = 22.46$, $p < .01$. Mean probability of inhibition on stop-trials across the four stop-signal tasks is shown in Figure 3.4. Examination of Figure 3.4 indicates that, as predicted, probability of inhibition on stop-trials was higher (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, higher on the Punishment task than on the Reward task and higher on the Punishment task than on the Conflict task.

Table 3.2

*Mean and Standard Deviation of Stop-signal Task Performance Measures across the Four Tasks*

| Measure | Stop-signal Task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | Punishment | | Reward | | Conflict | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *P* (Inhibition) | 0.55 | 0.23 | 0.64 | 0.23 | 0.43 | 0.24 | 0.48 | 0.15 |
| SSRT (msec) | 274 | 18.49 | 233 | 22.19 | 287 | 59.70 | 277 | 26.99 |
| MRT (msec) | 508 | 87.82 | 508 | 76.95 | 447 | 64.80 | 453 | 45.51 |
| No. of errors | 7.90 | 5.51 | 5.70 | 5.62 | 10.40 | 7.50 | 7.70 | 5.40 |

*Note.* n = 10; *P* (Inhibition) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; No. of errors = number of response errors made on go-trials.

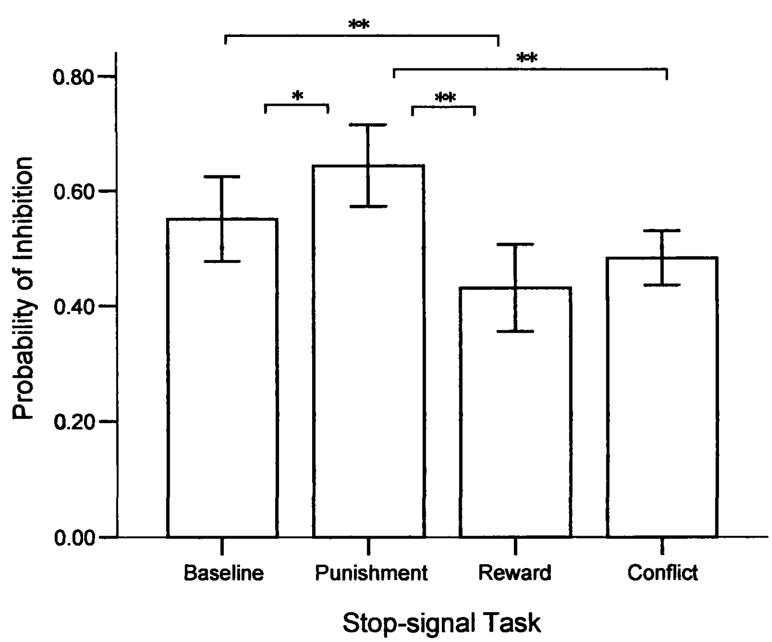


*Figure 3.4.* Mean probability of inhibition on stop-trials ( ± 1 SE) for Baseline (n = 10), Punishment (n = 10), Reward (n = 10), and Conflict (n = 10) stop-signal tasks.

**p* < .05. ***p* < .01.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed a significant mean difference between probability of inhibition on stop-trials on the Reward task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 12.96, p < .01$. Examination of Figure 3.4 indicates that, as predicted, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Reward task than on the Baseline task. Contrary to prediction, there was no significant mean difference between probability of inhibition on stop-trials on the Reward task and probability of inhibition on stop-trials on the Conflict task, $F(1, 9) = 1.98$, $p > .05$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between probability of inhibition on stop-trials on the Conflict task and probability of inhibition on stop-trials on the Baseline task, $F(1, 9) = 4.41, p > .05$.

*3.2.3.1.1.2 Stop-signal reaction time (SSRT)*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between SSRT on the Punishment task and SSRT on the Baseline task, $F(1, 9) = 55.05, p < .01$, the Reward task, $F(1, 9) = 14.64, p < .01$, and on the Conflict task, $F(1, 9) = 16.74, p < .01$. Mean SSRT across the four stop-signal tasks is shown in Figure 3.5. Examination of Figure 3.5 indicates that, as predicted, SSRT was faster (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, faster on the Punishment task than on the Reward task and faster on the Punishment task than on the Conflict task.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed, contrary to prediction, no significant mean difference between SSRT on the Reward task and SSRT on the Baseline task, $F(1, 9) = 0.60, p > .05$, or on the Conflict task, $F(1, 9) = 0.30$, $p > .05$.

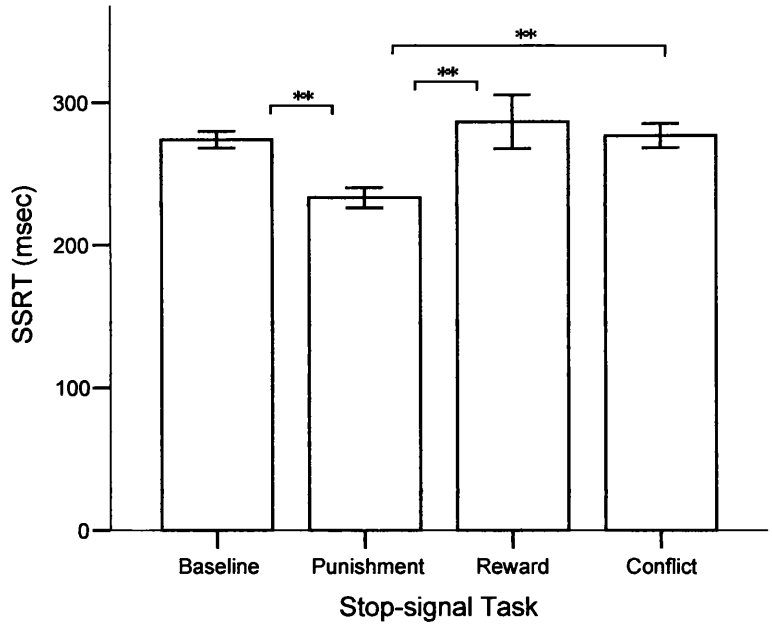


*Figure 3.5.* Mean stop-signal reaction time (SSRT) ( ± 1 SE) for Baseline (n = 10), Punishment (n = 10), Reward (n = 10), and Conflict (n = 10) stop-signal tasks.

*$p < .05$. **$p < .01$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between SSRT on the Conflict task and SSRT on the Baseline task, $F(1, 9) = 0.09, p > .05$.

*3.2.3.1.2 Response execution*

Doubly-MANOVA revealed significant multivariate effects for the main effect of Task on the two measures of response execution (MRT on go-trials and go-trial response accuracy), $F(6, 4) = 8.45$, $p < .05$; Wilks' Lambda = .07. Analysis of each individual dependent measure of response execution, using a Bonferroni adjusted alpha level of .025, showed that the four tasks differed in terms of MRT on go-trials, $F(3, 27) = 14.95, p < .01$, and in terms of go-trial response accuracy, $F(3, 27) = 4.11$, $p < .05$.

*3.2.3.1.2.1 Mean reaction time (MRT) on go-trials*

Pairwise comparisons revealed a significant mean difference between MRT on go-trials on the Reward task and MRT on go-trials on the Baseline task, $p < .05$, and on the Punishment task, $p < .05$. MRT on go-trials across the four stop-signal tasks is shown in Figure 3.6. Examination of Figure 3.6 indicates that MRT on go-trials on the Reward task was faster than on the Baseline task and faster than on the Punishment task.

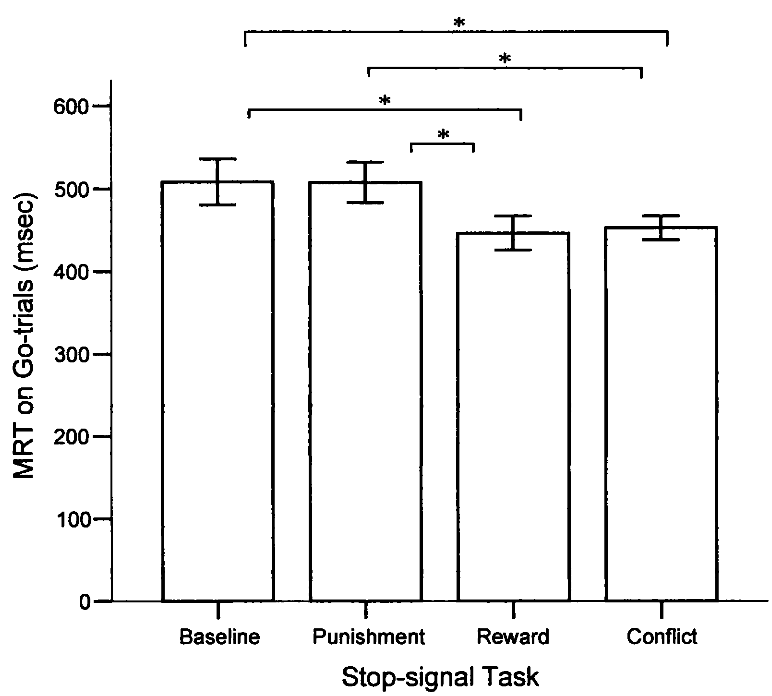


*Figure 3.6.* Mean reaction time (MRT) on go-trials ( ± 1 SE) for Baseline (n = 10), Punishment (n = 10), Reward (n = 10), and Conflict (n = 10) stop-signal tasks.

*$p < .05$.

There was a significant mean difference between MRT on go-trials on the Conflict task and MRT on go-trials on the Baseline task, $p < .05$, and on the Punishment task, $p < .05$. Examination of Figure 3.6 indicates that MRT on go-trials on the Conflict task was faster than on the Baseline task and faster than on the Punishment task. No other pairwise comparison involving MRT on go-trials was significant, $p > .05$.

*3.2.3.1.2.2 Go-trial response accuracy*

Pairwise comparisons revealed no significant mean differences when comparing go-trial response accuracy on each of the four stop-signal tasks with go-trial response accuracy on each of the other three stop-signal tasks, $p > .05$. Examination of means in Table 3.2 indicates that go-trial response accuracy was greatest on the Punishment task (mean 5.70 response errors), poorest on the Reward task (mean 10.40 response errors), and similar on the Baseline task as on the Conflict task (mean 7.90 and 7.70 response errors, respectively).

*3.2.3.2 Effects of stop-signal delay on probability of inhibition*

ANOVA revealed a significant main effect of Delay on probability of inhibition on stop-trials on the Baseline, $F(3, 27) = 36.91, p < .01$, Punishment (Greenhouse-Geisser correction), $F(1.87, 16.83) = 30.20, p < .01$, Reward, $F(3, 27) = 34.09, p < .01$, and Conflict (Greenhouse-Geisser correction), $F(1.77, 15.96) = 65.53, p < .01$, tasks. Figure 3.7 plots mean probability of inhibition at each stop-signal delay on each of the four stop-signal tasks. Figure 3.7 indicates that, as expected, probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay. This function was evident on all four tasks and polynomial within-subjects contrasts revealed these functions to be significant linear trends on the Baseline, $F(1, 9) = 66.85, p < .01$, Punishment, $F(1, 9) = 85.47, p < .01$, Reward, $F(1, 9) = 57.31, p < .01$, and Conflict, $F(1, 9) = 126.18, p < .01$, tasks. This indicates that, as predicted, probability of inhibition decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each on the four stop-signal tasks.

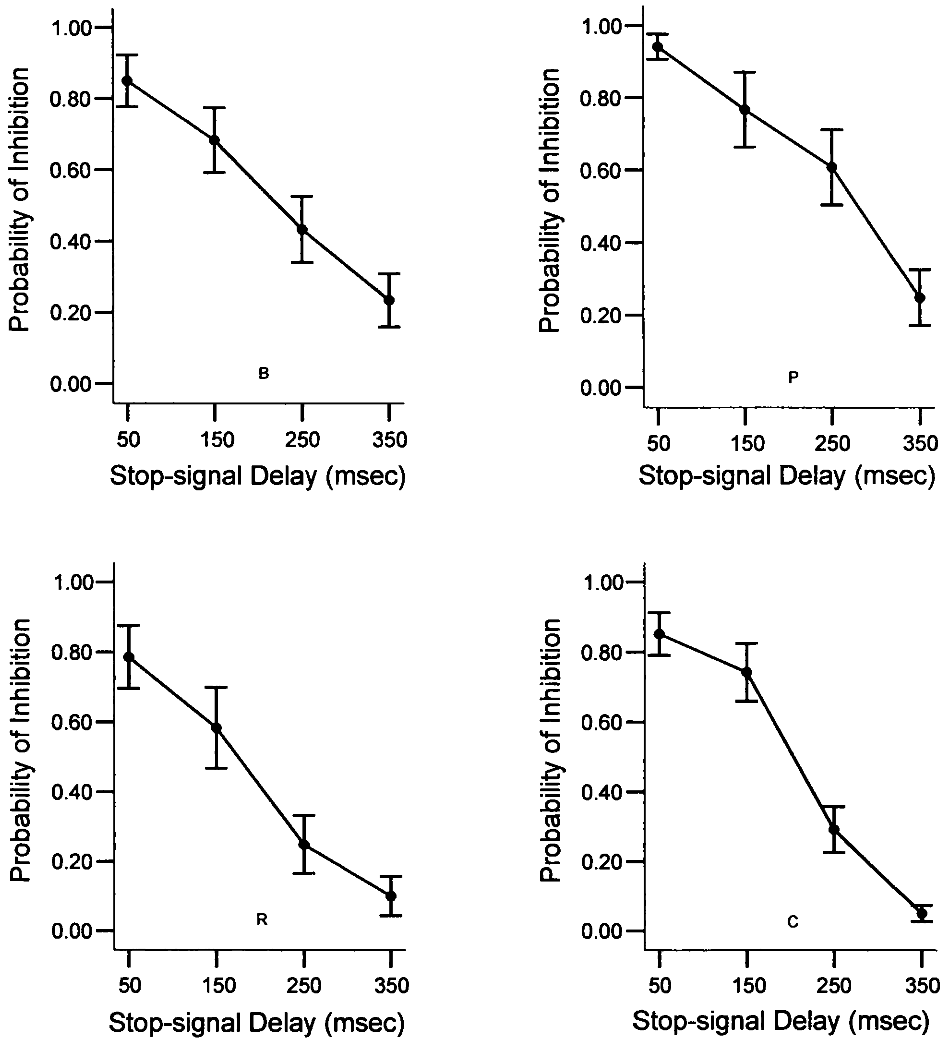


*Figure 3.7.* Mean probability of inhibition at each stop-signal delay ( ± 1 SE) on the Baseline (panel B), Punishment (panel P), Reward (panel R) and Conflict (panel C) stop-signal tasks.

### *3.2.4 Discussion*

Consistent with the findings of Experiment 1, the results obtained in the present study provided support for the idea that inhibitory control on the stop-signal task can be modified using different response contingencies. Significant evidence was found to support the prediction that inhibitory control should differ across the four stop-signal tasks with different response contingencies. It was predicted that, due to an increased care in performance resulting from the presence of specific punishing stimuli (in the form of points lost for errors made on go-trials and for lack of inhibition on stop-trials) on the Punishment stop-signal task, inhibitory control should be stronger on this task compared to on the Baseline, Reward, and Conflict tasks. Consistent with the findings of Experiment 1, participants in the present experiment stopped for a greater proportion of stop-signals (i.e., probability of inhibition on stop-trials was higher) and displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Punishment task compared to on the Baseline task. This finding provides evidence in support of the prediction that inhibitory control should be stronger on the Punishment stop-signal task compared to on the Baseline task. Also consistent with the findings of Experiment 1, participants in the present experiment stopped for a greater proportion of stop-signals (i.e., probability of inhibition on stop-trials was higher) on the Punishment task compared to on the Reward task and compared to on the Conflict task. However, unlike in Experiment 1, participants also displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Punishment task compared to on the Reward task and compared to on the Conflict task in the present experiment. This suggests that, with the modification of the stop-signal tasks so that the potency of the specific motivational stimuli was strengthened, evidence was produced to support predictions that inhibitory control should be stronger on the Punishment stop-signal task compared to on the Reward task and compared to on the Conflict task based on both measures of response inhibition (probability of inhibition on stop-trials and SSRT) rather than just on probability of inhibition on stop-trials (as in the findings of Experiment 1).

It was also predicted that, due to a decreased care in performance resulting from the presence of specific rewarding stimuli (in the form of points won for speeded responses on go-trials) on the Reward stop-signal task, inhibitory control should be weaker on this task compared to on the Baseline, Punishment, and Conflict tasks. Differences in inhibitory control on the Reward task compared to on the Punishment task have been discussed above. Unlike in Experiment 1, participants in the present experiment stopped for a smaller proportion of stop-signals (i.e., probability of inhibition on stop-trials was lower) on the Reward task compared to on the Baseline task. Thus, based on this measure of response inhibition, this finding supports the prediction that inhibitory control should be weaker on the Reward stop-signal task compared to on the Baseline task. However, participants showed no significant change in estimated time to inhibit a response (i.e., SSRT did not differ significantly) on the Reward task compared to on the Baseline task. Although not significant, the mean difference in SSRT between these two tasks was in the predicted direction so perhaps with a larger sample size this mean difference might become significant. Experiment 1 produced results suggesting that, contrary to expectations, SSRT was actually faster (i.e., inhibitory control was stronger) on the Reward task compared to on the Baseline task. The results obtained in the present experiment did not support this suggestion, indicating that the modifications made to strengthen the potency of the specific rewarding stimuli present on the Reward stop-signal task effected response inhibition in the desired manner. No significant evidence was obtained to support the prediction that inhibitory control should be weaker on the Reward task compared to on the Conflict task. Although not significant, mean differences in measures of response inhibition on the Reward task compared to on the Conflict task were in the predicted direction. This finding is consistent with the findings of Experiment 1. It is possible that the small sample size used in both the present experiment and in Experiment 1 was simply too small to produce significant differences in response inhibition between these two tasks and that had a larger sample size been used, the mean differences observed may have become significant differences.

Finally, it was predicted that, due to an increased motivation on go-trials combined with an increased care not to make errors resulting from the presence of both specific rewarding and punishing stimuli, inhibitory control should be: similar on the Conflict stop-signal task compared to on the Baseline task; weaker on the Conflict stop-signal task compared to on the Punishment task; and stronger on the Conflict stop-signal task compared to on the Reward task. Differences in inhibitory control on the Conflict task compared to on the Punishment and Reward tasks have been discussed above. Inhibitory control was found to be similar on the Conflict task compared to on the Baseline task, consistent with prediction and consistent with the findings of Experiment 1.

Consistent with the findings of Experiment 1 and with previous research using the same stop-signal delays (Fillmore & Rush, 2002; Fillmore et al., 2001, 2002), probability of inhibition was found to decrease in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each of the four tasks in the present experiment. This finding demonstrates that response inhibition was under some degree of stimulus control of the stop-signals on all four tasks.

*3.2.4.1 Task differences in response execution*

As well as effecting participants' response inhibition, the presence of different response contingencies effected participants' ability to execute responses on the stop-signal task, both in terms of their speed and accuracy on go-trials. This finding was contrary to the findings of Experiment 1, adding further support to the success of the effectiveness of the modifications made to the Punishment, Reward, and Conflict tasks used in the present experiment. Not only did the strengthened potency of the specific motivational stimuli on these tasks effect response inhibition in the desired manner across tasks, it was also strengthened enough to produce significant differences in both measures of response execution. The specific rewarding stimuli present on the Reward and Conflict stop-signal tasks was strong enough to significantly reduce participants' MRT on go-trials on these tasks compared to on the Baseline and Punishment tasks. These findings show that the specific rewarding stimuli present on these tasks had the desired effect of enhancing the appetitive properties of the go-task stimuli (i.e., the letters without a stop-signal) increasing participants' interest and motivation in approaching (with a computer key press response) this stimuli.

Participants' go-trial response accuracy differed significantly across the stop-signal tasks with different response contingencies. Although no differences in go-trial response accuracy between individual tasks were found to be significant, the mean differences between tasks indicated that go-trial response accuracy was strongest on the Punishment task, weakest on the Reward task, and similar on the Conflict task as on the Baseline task. This suggests that the specific punishing stimuli present on the Punishment task was strong enough to result in participants taking greater care in responding correctly on go-trials and that the specific rewarding stimuli present on the Reward task was strong enough to result in participants taking less care in responding correctly on go-trials due to their increased motivation to respond with speed. Perhaps the mean differences in go-trial response accuracy between tasks observed in the present experiment would have been found to be significant differences had a larger sample size been used. The additional findings of differences in response execution on the tasks in the present experiment indicate that these four stop-signal tasks with different response contingencies have the potential to provide additional, new and intriguing insights into inhibitory control and performance on the stop-signal task.

## 3.3 Experiment 3

### *3.3.1 Aims and experimental predictions*

#### *3.3.1.1 Aims*

Experiment 3 was organised to replicate the findings of Experiment 2 in a larger sample of participants. The four stop-signal tasks used in Experiment 2 yielded promising results, both in terms of task differences in response inhibition and response execution, in a small sample size (n = 10). The present experiment aimed to replicate these promising findings, using the same four tasks, in a considerably larger and, therefore, more reliably representative sample.

#### *3.3.1.2 Experimental predictions*

Predictions concerning response inhibition were the same as in Experiments 1 and 2. Based on the findings of Experiment 2, additional predictions were also made concerning response execution on the four tasks. Experiment 2 found that response execution differed across the four stop-signal tasks, both in terms of MRT on go-trials and go-trial response accuracy. Thus, it was predicted that this same finding would be replicated in the present experiment. More specifically, it was predicted that an increased care in performance on the Punishment stop-signal task, caused by the presence of specific punishing stimuli, should result in greater go-trial response accuracy on this task compared to on the Baseline, Reward, and Conflict tasks. It was also predicted that an increased motivation on go-trials on the Reward stop-signal task, caused by the presence of specific rewarding stimuli, should result in: a faster MRT on go-trials on the Reward stop-signal task compared to on the Baseline and Punishment tasks; and poorer go-trial response accuracy on the Reward stop-signal task compared to on the Baseline, Punishment, and Conflict tasks. Finally, it was predicted that an increased motivation on go-trials combined with an increased care not to make errors on the Conflict stop-signal task, caused by the presence of both specific rewarding and punishing stimuli, should result in: a faster MRT on go-trials and similar go-trial response accuracy on the Conflict stop-signal task compared to on the Baseline task; a faster MRT on go-trials and poorer go-trial response accuracy on the Conflict stop-signal task compared to on the Punishment task; and greater go-trial response accuracy on the Conflict stop-signal task compared to on the Reward task.

### *3.3.2 Method*

#### *3.3.2.1 Participants*

Forty undergraduate students (9 males, 31 females), studying psychology at Swansea University, participated. Participants' ages ranged between 18 and 25 years (mean = 20.20, S.D. = 1.74). They were recruited by means of volunteer or self-selected sampling methods using a subject pool credit website, and gave their written informed consent to take part in the experiment after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded course credits for their participation.

#### *3.3.2.2 Materials and design*

The four stop-signal tasks (Baseline, Punishment, Reward, and Conflict) were the same as those used in Experiment 2; described in detail in chapter 2, section 2.1.1. The written Baseline, Punishment, Reward, and Conflict task instructions given to participants were the same as those in Experiment 2 and are shown in full in Appendices A, E, F, and G, respectively. The order of task administration was the same as in Experiments 1 and 2 (see section 3.1.2.2.2).

*3.3.2.3 Procedure*

The procedure followed was identical to the one detailed in section 3.2.1.3 of Experiment 2.

*3.3.2.4 Dependent measures and data analyses of stop-signal task performance*

*3.3.2.4.1 Dependent measures of stop-signal task performance*

Dependent measures of stop-signal task performance in the present experiment were identical to those in Experiments 1 and 2 (see section 3.1.2.4.1).

*3.3.2.4.2 Data analyses of stop-signal task performance*

*3.3.2.4.2.1 Order effects*

Effects of the counterbalancing variable Order on the four dependent measures of stop-signal task performance across Task were analysed by mixed multivariate analysis of variance (MANOVA) with Order (Punishment task before Reward task or Reward task before Punishment task) as the between-subjects factor. Adjustment was made for four covariates: baseline probability of inhibition on stop-trials, baseline SSRT, baseline MRT on go-trials and baseline go-trial response accuracy. Baseline task performance measures were included as covariates to assess the effect of Order on task performance measures after adjusting for initial differences in stop-signal task performance. The within-subjects factor treated multivariately was the three Tasks performed after the Baseline task: the Punishment, Reward, and Conflict tasks.

Preliminary analyses identified one case, in the group that performed the Reward task before the Punishment task, with a probability of inhibition score of 0.00 on the Baseline task. This case was removed from analysis since the probability of inhibition score of 0.00 means the participant demonstrated failure to inhibit responses to go-stimuli on all stop-trials, making it impossible to calculate SSRT, and, most probably, this reflects a misunderstanding of the task requirements. Two cases in the group that performed the Punishment task before the Reward task, one with an extremely high z score (beyond the $p = .001$ criterion of 3.29, two-tailed) on SSRT on the Baseline task and another with an extremely high z score on go-trial response accuracy on the Baseline task, were found to be univariate outliers. One case in the group that performed the Reward task before the Punishment task, with extremely high z scores on SSRT on the Baseline, Punishment, and Conflict tasks, was found to be univariate outlier. The outliers were deleted, leaving 36 cases for analysis: $N = 18$ for both Orders. There were no multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy). There was no significant main effect of Order, $F(4, 27) = 1.64, p > .05$; Wilks' Lambda = .81, and no significant interaction between Order and Task, $F(8, 23) = 1.85, p > .05$; Wilks' Lambda = .61. Since none of the main effects or interactions involving Order was significant, data were collapsed for subsequent analyses.

*3.3.2.4.2.2 Task effects*

Task effects on the four dependent measures of stop-signal task performance (the two criterion measures of response inhibition: probability of inhibition on stop-trials and SSRT; and the two criterion measures of response execution: MRT on go-trials and go-trial response accuracy) were analysed by doubly-multivariate analysis of variance (MANOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor treated multivariately. Follow-up repeated measures ANOVAs generated by the overall doubly-MANOVA were used to analyse each individual dependent measure of task performance across Task. Specific hypotheses concerning task differences in response inhibition and response execution between individual tasks were tested using simple within-subjects contrasts.

*3.3.2.4.2.3 Effects of stop-signal delay on probability of inhibition*

Effects of stop-signal delay on probability of inhibition on stop-trials were analysed by separate one-way repeated measure analysis of variance (ANOVA) with Delay (50, 150, 250 and 350-ms) as the within-subjects factor. Polynomial within-subjects contrasts were used to test the hypotheses that probability of inhibition should decrease in a linear fashion across the four stop-signal delays, from 50 to 350-ms, on each stop-signal task.

*3.3.3 Results*

Preliminary analyses identified one case with a probability of inhibition score of 0.00 on the Baseline task. This case was removed from analysis since the probability of inhibition score of 0.00 means the participant demonstrated failure to inhibit responses to go-stimuli on all stop-trials, making it impossible to calculate SSRT, and, most probably, this reflects a misunderstanding of the task requirements. Five cases, one with extremely high z scores (beyond the $p = .001$ criterion of 3.29, two-tailed) on SSRT on the Baseline, Punishment, and Conflict tasks, another with an extremely high z score on SSRT on the Baseline task, one with an extremely high z score on go-trial response accuracy on the Baseline task, another with an extremely high z score on go-trial response accuracy on the Reward task, and one with an extremely high z score on MRT on go-trials on the Conflict task, were found to be univariate outliers. The outliers were deleted, leaving 34 cases for analysis. There were no multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

*3.3.3.1 Task effects on stop-signal task performance*

Doubly-MANOVA revealed significant multivariate effects for the main effect of Task on the four dependent measures of stop-signal task performance, $F(12, 22) = 16.54, p < .01$; Wilks' Lambda = .10. Follow-up ANOVAs revealed that the four tasks differed in terms of probability of inhibition on stop-trials, $F(3, 99) = 35.46, p < .01$, SSRT (Greenhouse-Geisser correction), $F(2.26, 74.54) = 6.81, p < .01$, MRT on go-trials (Greenhouse-Geisser correction), $F(1.57, 51.91) = 42.29, p < .01$, and go-trial response accuracy, $F(3, 99) = 11.71, p < .01$. This indicates that, consistent with prediction, mean measures of response inhibition (probability of inhibition on stop-trials and SSRT) and mean measures of response execution (MRT on go-trials and go-trial response accuracy) differed across the four tasks with different response contingencies. Means and standard deviations of stop-signal task performance measures across the four tasks are shown in Table 3.3.

Table 3.3

*Mean and Standard Deviation of Stop-signal Task Performance Measures across the Four Tasks*

| Measure | Stop-signal Task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | Punishment | | Reward | | Conflict | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *P* (Inhibition) | 0.57 | 0.15 | 0.70 | 0.19 | 0.48 | 0.18 | 0.54 | 0.15 |
| SSRT (msec) | 273 | 34.01 | 241 | 28.61 | 273 | 48.86 | 255 | 34.26 |
| MRT (msec) | 506 | 58.75 | 524 | 80.58 | 452 | 50.26 | 456 | 50.86 |
| No. of errors | 6.21 | 3.80 | 4.91 | 3.92 | 9.09 | 5.60 | 7.12 | 4.22 |

*Note.* n = 34; *P* (Inhibition) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; No. of errors = number of response errors made on go-trials.

#### 3.3.3.1.1 Response inhibition

##### 3.3.3.1.1.1 Probability of inhibition on stop-trials

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Punishment task and probability of inhibition on stop-trials on the Baseline task, $F(1, 33) = 25.03$, $p < .01$, the Reward task, $F(1, 33) = 79.92$, $p < .01$, and on the Conflict task, $F(1, 33) = 66.68$, $p < .01$. Mean probability of inhibition on stop-trials across the four stop-signal tasks is shown in Figure 3.8. Examination of Figure 3.8 indicates that, as predicted, probability of inhibition on stop-trials was higher (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, higher on the Punishment task than on the Reward task and higher on the Punishment task than on the Conflict task.

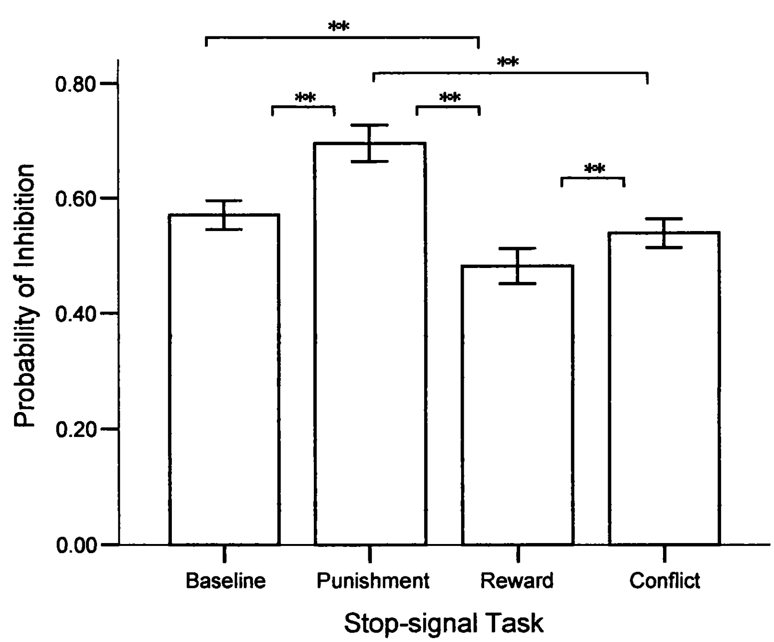


*Figure 3.8.* Mean probability of inhibition on stop-trials ( ± 1 SE) for Baseline (n = 34), Punishment (n = 34), Reward (n = 34), and Conflict (n = 34) stop-signal tasks.

$^{**}p < .01$.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Reward task and probability of inhibition on stop-trials on the Baseline task, $F(1, 33) = 22.09, p < .01$, and on the Conflict task, $F(1, 33) = 8.37, p < .01$. Examination of Figure 3.8 indicates that, as predicted, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Reward task than on the Baseline task and lower on the Reward task than on the Conflict task.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between probability of inhibition on stop-trials on the Conflict task and probability of inhibition on stop-trials on the Baseline task, $F(1, 33) = 2.19, p > .05$.

*3.3.3.1.1.2 Stop-signal reaction time (SSRT)*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between SSRT on the Punishment task and SSRT on the Baseline task, $F(1, 33) = 24.96, p < .01$, the Reward task, $F(1, 33) = 10.41, p < .01$, and on the Conflict task, $F(1, 33) = 4.91, p < .05$. Mean SSRT across the four stop-signal tasks is shown in Figure 3.9. Examination of Figure 3.9 indicates that, as predicted, SSRT was faster (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, faster on the Punishment task than on the Reward task and faster on the Punishment task than on the Conflict task.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed, contrary to prediction, no significant mean difference between SSRT on the Reward task and SSRT on the Baseline task, $F(1, 33) = 0.00, p > .05$. There was a near significant mean difference between SSRT on the Reward task and SSRT on the Conflict task, $F(1, 33) = 3.08$, $p = .09$. Examination of Figure 3.9 indicates that, consistent with prediction, SSRT was slower (i.e., inhibitory control was weaker) on the Reward task than on the Conflict task.

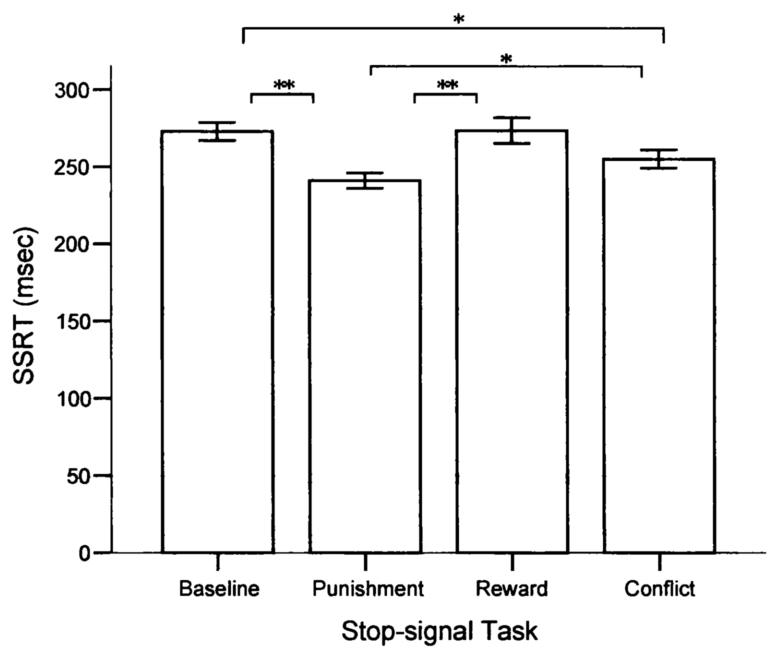


*Figure 3.9.* Mean stop-signal reaction time (SSRT) ( ± 1 SE) for Baseline (n = 34), Punishment (n = 34), Reward (n = 34), and Conflict (n = 34) stop-signal tasks.

**p* < .05. ***p* < .01.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, contrary to prediction, a significant mean difference between SSRT on the Conflict task and SSRT on the Baseline task, $F(1, 33) = 5.10, p < .05$. Examination of Figure 3.9 indicates that SSRT was faster (i.e., inhibitory control was stronger) on the Conflict task than on the Baseline task.

*3.3.3.1.2 Response execution*

*3.3.3.1.2.1 Mean reaction time (MRT) on go-trials*

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between MRT on go-trials on the Reward task and MRT on go-trials on the Baseline task, $F(1, 33) = 55.05, p < .01$, and on the Punishment task,

$F(1, 33) = 49.00, p < .01$. Mean MRT on go-trials across the four stop-signal tasks is shown in Figure 3.10. Examination of Figure 3.10 indicates that, as predicted, MRT on go-trials was faster on the Reward task than on the Baseline task and faster on the Reward task than on the Punishment task. There was no significant mean difference between MRT on go-trials on the Reward task and MRT on go-trials on the Conflict task, $F(1, 33) = 1.42, p > .05$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed significant mean differences between MRT on go-trials on the Conflict task and MRT on go-trials on the Baseline task, $F(1, 33) = 75.71, p < .01$, and on the Punishment task, $F(1, 33) = 55.22, p < .01$. Examination of Figure 3.10 indicates that, as predicted, MRT on go-trials was faster on the Conflict task than on the Baseline task and faster on the Conflict task than on the Punishment task.

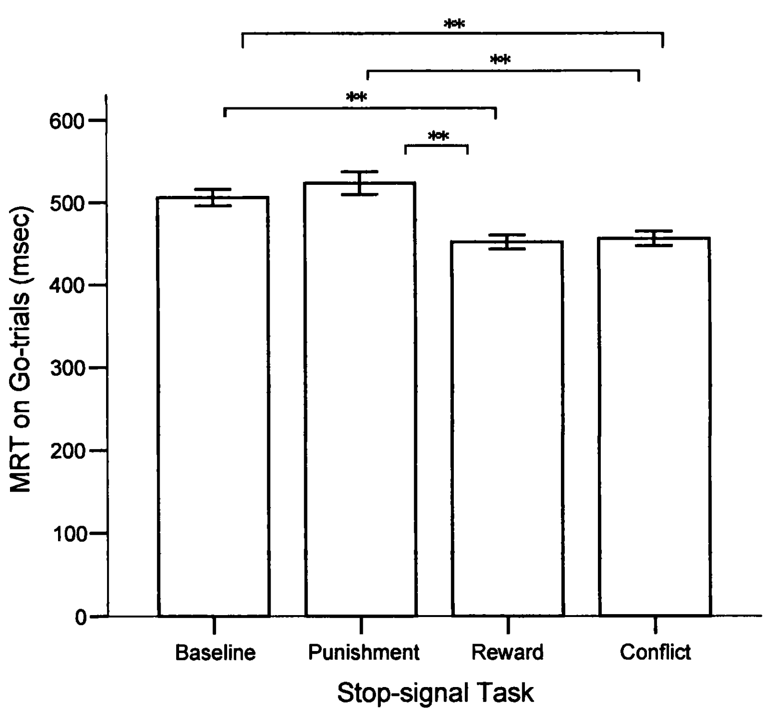


*Figure 3.10.* Mean reaction time (MRT) on go-trials ( ± 1 SE) for Baseline (n = 34), Punishment (n = 34), Reward (n = 34), and Conflict (n = 34) stop-signal tasks.

$^{**}p < .01$.

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed no significant mean difference between MRT on go-trials on the Punishment task and MRT on go-trials on the Baseline task, $F(1, 33) = 2.69, p > .05$.

*3.3.3.1.2.2 Go-trial response accuracy*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between the number of response errors made on go-trials on the Punishment task and the number of response errors made on go-trials on the Reward task, $F(1, 33) = 25.13, p < .01$, and on the Conflict task, $F(1, 33) = 11.02, p < .01$. There was a near significant mean difference between the number of response errors made on go-trials on the Punishment task and the number of response errors made on go-trials on the Baseline task, $F(1, 33) = 3.68, p = .06$. Mean number of response errors made on go-trials across the four stop-signal tasks is shown in Figure 3.11. Examination of Figure 3.11 indicates that, as predicted, the number of response errors made on go-trials was fewer (i.e., go-trial response accuracy was greater) on the Punishment task than on the Baseline task, fewer on the Punishment task than on the Reward task and fewer on the Punishment task than on the Conflict task.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between the number of response errors made on go-trials on the Reward task and the number of response errors made on go-trials on the Baseline task, $F(1, 33) = 14.71, p < .01$, and on the Conflict task, $F(1, 33) = 25.13, p < .01$. Examination of Figure 3.11 indicates that, as predicted, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Reward task than on the Baseline task and greater on the Reward task than on the Conflict task.

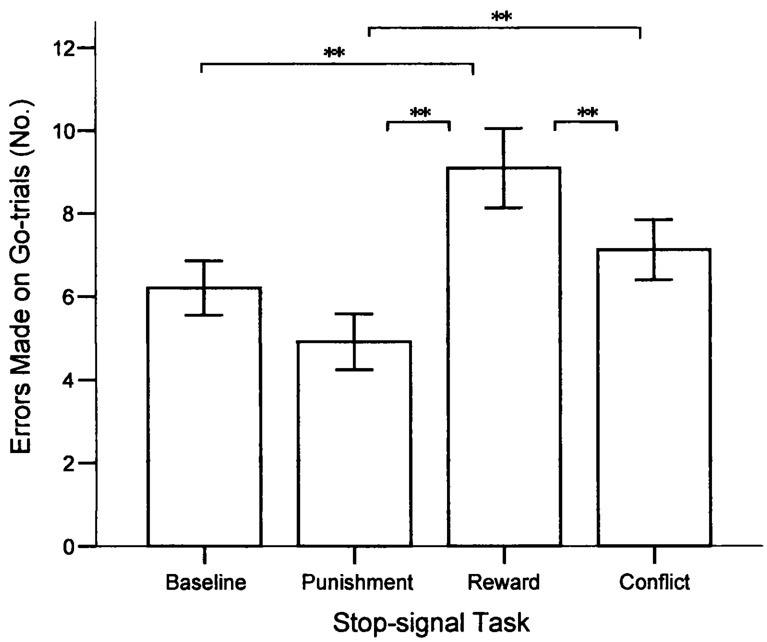


*Figure 3.11.* Mean number of response errors made on go-trials ( ± 1 SE) for Baseline (n = 34), Punishment (n = 34), Reward (n = 34), and Conflict (n = 34) stop-signal tasks.

**$p < .01$.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between the number of response errors made on go-trials on the Conflict task and the number of response errors made on go-trials on the Baseline task, $F(1, 33) = 1.45, p > .05$.

### *3.3.3.2 Effects of stop-signal delay on probability of inhibition*

ANOVA revealed a significant main effect of Delay on probability of inhibition on stop-trials on the Baseline, $F(3, 99) = 185.14, p < .01$, Punishment (Greenhouse-Geisser correction), $F(2.00, 66.06) = 109.96, p < .01$, Reward (Greenhouse-Geisser correction), $F(2.16, 71.12) = 188.49$, $p < .01$, and Conflict (Greenhouse-Geisser correction), $F(2.47, 81.43) = 224.34, p < .01$, tasks. Figure 3.12 plots mean probability of inhibition at each stop-signal delay on each of the four stop-signal tasks. Figure 3.12 indicates that, as expected, probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay. This function was evident on all four tasks and polynomial within-subjects contrasts revealed these functions to be significant linear trends on the Baseline, $F(1, 33) = 624.06, p < .01$, Punishment, $F(1, 33) = 170.20, p < .01$, Reward, $F(1, 33) = 643.96$, $p < .01$, and Conflict, $F(1, 33) = 912.40, p < .01$, tasks. This indicates that, as predicted, probability of inhibition decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each on the four stop-signal tasks.

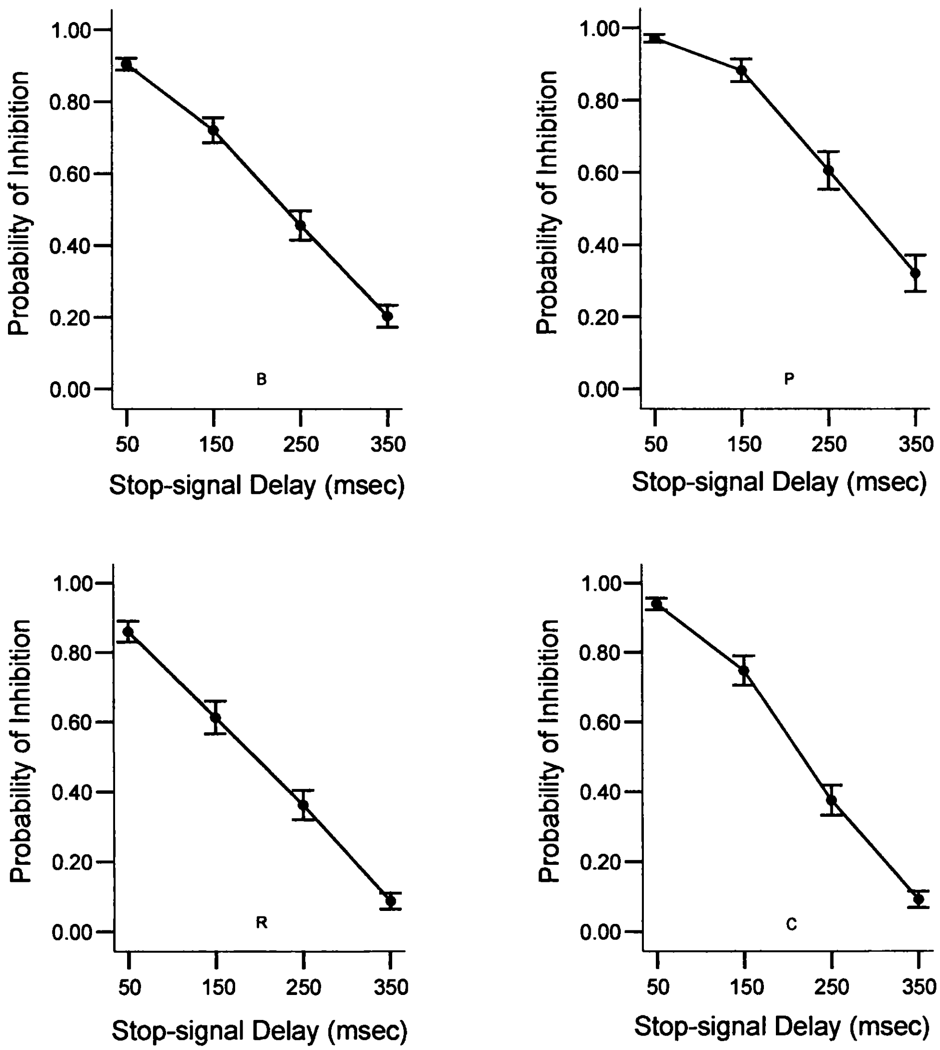


*Figure 3.12.* Mean probability of inhibition at each stop-signal delay ( ± 1 SE) on the Baseline (panel B), Punishment (panel P), Reward (panel R) and Conflict (panel C) stop-signal tasks.

### 3.3.4 Discussion

Consistent with the findings of Experiments 1 and 2, the results obtained in the present experiment provided support for the idea that inhibitory control on the stop-signal task can be modified using different response contingencies. Significant evidence was found to support the prediction that inhibitory control should differ across the four stop-signal tasks with different response contingencies. Consistent with the findings of Experiment 2, participants in the present experiment stopped for a greater proportion of stop-signals (i.e., probability of inhibition on stop-trials was higher) and displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Punishment stop-signal task compared to on the Baseline, Reward, and Conflict tasks. These findings provide evidence in support of predictions that, due to an increased care in performance resulting from the presence of specific punishing stimuli (in the form of points lost for errors made on go-trials and for lack of inhibition on stop-trials) on the Punishment stop-signal task, inhibitory control should be stronger on this task compared to on the Baseline, Reward, and Conflict tasks.

It was also predicted that, due to a decreased care in performance resulting from the presence of specific rewarding stimuli (in the form of points won for speeded responses on go-trials) on the Reward stop-signal task, inhibitory control should be weaker on this task compared to on the Baseline, Punishment, and Conflict tasks. Differences in inhibitory control on the Reward task compared to on the Punishment task have been discussed above. Participants stopped for a smaller proportion of stop-signals (i.e., probability of inhibition on stop-trials was lower) and displayed a (nearly significant) slower estimated time to inhibit a response (i.e., SSRT was slower) on the Reward task compared to on the Conflict task. This finding provides evidence in support of the prediction that inhibitory control should be weaker on the Reward stop-signal task compared to on the Conflict task. Experiment 2 found non-significant mean differences on the two measures of response inhibition between these two tasks in the predicted direction and so it was anticipated that these differences might prove significant in a larger sample. The results obtained in the present experiment show that this was indeed the case.

Consistent with the findings of Experiment 2, participants in the present experiment stopped for a smaller proportion of stop-signals (i.e., probability of inhibition on stop-trials was lower) on the Reward task compared to on the Baseline task. Thus, based on this measure of response inhibition, this finding supports the prediction that inhibitory control should be weaker on the Reward stop-signal task compared to on the Baseline task. However, participants showed no significant change in estimated time to inhibit a response (i.e., SSRT did not differ significantly) on the Reward task compared to on the Baseline task. Although unexpected, this finding is actually consistent with the findings of Experiment 2. However, because Experiment 2 revealed non-significant mean differences in SSRT between these two tasks to be in the predicted direction, it was anticipated that these differences might prove significant in a larger sample. The results obtained in the present experiment have shown this not to be the case. Instead, they have shown strong replication of the results obtained in Experiment 2.

It was predicted that, due to an increased motivation on go-trials combined with an increased care not to make errors resulting from the presence of both specific rewarding and punishing stimuli, inhibitory control should be: similar on the Conflict stop-signal task compared to on the Baseline task; weaker on the Conflict stop-signal task compared to on the Punishment task; and stronger on the Conflict stop-signal task compared to on the Reward task. Differences in inhibitory control on the Conflict task compared to on the Punishment and Reward tasks have been discussed above. Surprisingly, participants displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Conflict task compared to on the Baseline task. This suggests that, based on this measure of response inhibition, inhibitory control was stronger on the Conflict task than it was on the Baseline task, contrary to prediction. However, the lack of a significant mean difference in participants' probability of inhibition on stop-trials between these two tasks does not support this suggestion. Together, these findings indicate that participants' SSRT accelerated on the Conflict task compared to on the Baseline task to such a minimal, albeit significant, degree that it did not result in them stopping for a larger proportion of stop-signals on the Conflict task compared to on the

Baseline task and that, therefore, consistent with prediction and with the findings of Experiment 2, inhibitory control was similar on these two tasks.

Consistent with the findings of Experiments 1 and 2 and with previous research using the same stop-signal delays (Fillmore & Rush, 2002; Fillmore et al., 2001, 2002), probability of inhibition was found to decrease in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each of the four tasks in the present experiment. This finding demonstrates that response inhibition was under some degree of stimulus control of the stop-signals on all four tasks.

*3.3.4.1 Task differences in response execution*

As predicted, significant results were obtained showing that, as well as effecting participants' response inhibition, the presence of different response contingencies effected participants' ability to execute responses on the stop-signal task, both in terms of their speed and accuracy on go-trials. This finding was consistent with the findings of Experiment 2. It was predicted that an increased care in performance on the Punishment stop-signal task, caused by the presence of specific punishing stimuli, should result in greater go-trial response accuracy on this task compared to on the Baseline, Reward, and Conflict tasks. This prediction was supported by significant evidence when comparing the Punishment task with the Reward and Conflict tasks and by near significant evidence when comparing the Punishment task with the Baseline task. These predictions were based on the findings of Experiment 2, in which non-significant mean differences in go-trial response accuracy between these pairs of tasks were found to be in these same directions and so it was anticipated that these differences might prove significant in a larger sample. The results obtained in the present experiment show that this was indeed the case.

Other predictions concerning task differences in response execution were that an increased motivation on go-trials on the Reward stop-signal task, caused by the presence of specific rewarding stimuli, should result in: a faster MRT on go-trials on the Reward stop-signal task compared to on the

Baseline and Punishment tasks; and poorer go-trial response accuracy on the Reward stop-signal task compared to on the Baseline, Punishment, and Conflict tasks. Significant evidence was produced in support of each of these predictions. The findings concerning differences in MRT on go-trials between these tasks were consistent with the findings of Experiment 2, showing good replication of results. The predictions concerning go-trial response accuracy were based on the findings of Experiment 2, in which non-significant mean differences in go-trial response accuracy between these pairs of tasks were found to be in these same directions and so it was anticipated that these differences might prove significant in a larger sample. The results obtained in the present experiment show that this was indeed the case.

It was also predicted that an increased motivation on go-trials combined with an increased care not to make errors on the Conflict stop-signal task, caused by the presence of both specific rewarding and punishing stimuli, should result in: a faster MRT on go-trials and similar go-trial response accuracy on the Conflict stop-signal task compared to on the Baseline task; a faster MRT on go-trials and poorer go-trial response accuracy on the Conflict stop-signal task compared to on the Punishment task; and greater go-trial response accuracy on the Conflict stop-signal task compared to on the Reward task. Significant evidence was produced in support of each of these predictions. The findings concerning response execution on the Conflict task compared to on the Baseline task were consistent with the findings of Experiment 2, showing good replication of results.

### 3.4 General discussion

The purpose of this study was to develop stop-signal tasks with different response contingencies in order to investigate the effects of these different response contingencies on inhibitory control and task performance. Toward this end, a 'standard' task was used to measure baseline motor inhibition without specific motivational stimuli, a 'punishment' task with specific punishing motivational stimuli included was used to create an avoidance situation, a 'reward' task with specific rewarding motivational stimuli included was used to create an approach situation and a 'conflict' task with both specific rewarding and punishing motivational stimuli included was used to create an approach-avoidance conflict situation. Consistent with expectations, the results obtained in the present study provided support for the idea that inhibitory control on the stop-signal task can be modified using different response contingencies. All three experiments produced significant evidence in support of the prediction that inhibitory control should differ across the four tasks. In addition, both Experiments 2 and 3 found significant differences in measures of response execution, both in terms of speed and accuracy on go-trials, across the tasks with different response contingencies.

No previous research has investigated the influence of these four stop-signal task contingencies on inhibitory control and task performance within-subjects. Oosterlaan and Sergeant (1997) used a stop-signal task with reward contingencies and a stop-signal task with response cost contingencies to examine whether AD/HD children's impaired response inhibition on the stop-signal paradigm reflects a motivation deficit. Unlike in the present study, children earned credits for successful response inhibition (i.e., successfully stopping for stop-signals) in Oosterlaan and Sergeant's reward condition and their study did not allow them to determine the effects of rewarding and punishing response contingencies on the stop-signal task as such, since they did not include a condition in which there was no specific motivational stimuli. In the present study, the specific rewarding stimuli was associated with successful response execution (i.e., responding fast with the correct key) rather than with successful response inhibition as a means of enhancing the appetitive properties of the go-task stimuli (i.e., the letters without a stop-signal) increasing participants' interest and motivation in approaching (with a computer key press response) this stimuli on both the Reward and Conflict tasks. By not including a condition in which there was no specific motivational stimuli, Oosterlaan and Sergeant left open the possibility that response contingencies affect inhibitory control relative to no specific motivational stimuli. The results obtained in the present study show that different response contingencies did affect inhibitory control on the stop-signal task relative to no specific motivational stimuli.

Although the specific motivational stimuli included in the Punishment, Reward, and Conflict tasks in Experiment 1 had the expected effect of inducing significantly different response inhibition across the four tasks, it was not sufficiently potent to effect response inhibition in the expected manner between each individual task. Strengthening the potency of the specific motivational stimuli present on these tasks had the desired effect of revealing more significant differences in response inhibition between individual tasks in the predicted directions in Experiment 2. The results yielded from the modified tasks in Experiment 2 were then replicated in a larger sample in Experiment 3. As predicted, due to an increased care in performance resulting from the presence of specific punishing stimuli (in the form of points lost for errors made on go-trials and for lack of inhibition on stop-trials) on the Punishment stop-signal task, inhibitory control was found to be stronger on the Punishment task compared to on the other three tasks. This stronger inhibitory control was reflected in participants stopping for a greater proportion of stop-signals (i.e., higher probability of inhibition on stop-trials) and displaying a faster estimated time to inhibit a response (i.e., faster SSRT) on the Punishment task compared to on the Baseline, Reward, and Conflict tasks.

Also consistent with prediction, due to a decreased care in performance resulting from the presence of specific rewarding stimuli (in the form of points won for speeded responses on go-trials) on the Reward stop-signal task, inhibitory control was found to be weaker on the Reward task compared to on the other three tasks. This weaker inhibitory control was reflected in participants stopping for a smaller proportion of stop-signals (i.e., lower probability of inhibition on stop-trials) and displaying a slower estimated time to inhibit a response (i.e., slower SSRT) on the Reward task compared to on the Punishment and Conflict tasks. However, when comparing response inhibition on the Reward task with response inhibition on the Baseline task this weaker inhibitory control was only reflected in participants stopping for a smaller proportion of stop-signals (i.e., lower probability of inhibition on stop-trials) on the Reward task. Participants were not found to display a slower estimated time to inhibit a response (i.e., slower SSRT) on the Reward task compared to on the Baseline task. This suggests that the presence of specific rewarding stimuli on the Reward stop-signal task might have reduced inhibitions compared to on the Baseline task by some other mechanism that did not involve slowing of inhibitory processes.

Fillmore et al. (2002) found that acute administrations of cocaine reduced the proportion of successfully inhibited responses on stop-trials without slowing SSRT and reasoned that, instead of slowing the inhibitory processes making it less likely that they can be completed before response execution occurs (Logan & Cowan, 1984), cocaine might disrupt the initiation of the inhibitory process so that it fails to occur occasionally, resulting in less inhibitions on stop-trials. One possible explanation then for the finding in the present study that the presence of specific rewarding stimuli reduced the proportion of successfully inhibited responses on stop-trials without slowing SSRT on the Reward task compared to on the Baseline task is that the presence of specific rewarding stimuli might disrupt the initiation of the inhibitory process so that it fails to occur occasionally, resulting in less inhibitions on stop-trials. However, in Fillmore et al.'s study, the acute administration of cocaine was found to impair the ability to inhibit behavioural responses without affecting the ability to execute responses whereas, in the present study, as well as reducing the proportion of successfully inhibited responses on stop-trials, the presence of specific rewarding stimuli significantly reduced MRT on go-trials and significantly reduced go-trial response accuracy on the Reward task compared to on the Baseline task. This reduction in MRT on go-trials could explain the reduced proportion of successfully inhibited responses on stop-trials on the Reward task compared to on the Baseline task. It could be that, instead of slowing the inhibitory processes making it less likely that they can be completed before response execution occurs, the presence of specific rewarding stimuli speeds up response execution resulting in less inhibitions on stop-trials. Regardless of the cause, the presence of specific rewarding stimuli on the Reward stop-signal task was found to impair the ability to inhibit behavioural responses compared to on the Baseline stop-signal task (with no specific motivational stimuli).

Inhibitory control was found to be similar on the Conflict task compared to on the Baseline task, consistent with prediction. Contrary to the findings of the present study, Rodriguez-Fornells et al.

(2002) found that the proportion of successfully inhibited responses on stop-trials increased and SSRT decreased during performance of their stop-signal task with specific rewarding/punishing stimuli (i.e., their version of the Conflict task creating an approach-avoidance conflict situation) compared to during performance of the standard task, indicating an increased inhibitory control on the stop-signal task in the presence of specific rewarding and punishing stimuli. However, because Rodriguez-Fornells et al. reversed the assignment of responses to the two subsets of stimulus letters in their conflict condition (which was always the second condition) compared to their standard condition (the first condition) in an attempt to avoid practise effects, participants first had to inhibit the learned response from the first (standard) condition and then respond in the new way whilst performing the second (conflict) condition, resulting in an unreliable comparison between the two tasks. In the present study, the assignment of responses to the two subsets of stimulus letters were kept the same for all four conditions (tasks) to allow for a more reliable comparison between the four tasks. The order of task administration was counterbalanced across participants in an attempt to control for any possible confounding extraneous variables (e.g., practise effects) and then any order effects were investigated. No task order effects were revealed in any of the three experiments.

Although, in Experiment 1, the presence of different response contingencies had no effect on participants' ability to execute responses on the stop-signal task, in terms of their speed and accuracy on go-trials, this was not the case in Experiments 2 and 3. The strengthened (compared to Experiment 1) potency of the specific motivational stimuli present on the Punishment, Reward, and Conflict tasks in Experiment 2 significantly affected response execution, both in terms of speed and accuracy on go-trials, across the four tasks. This finding was then replicated in a larger sample in Experiment 3. As predicted, the specific punishing stimuli present on the Punishment stop-signal task resulted in participants having a greater go-trial response accuracy on this task compared to on the other three tasks, the specific rewarding stimuli present on the Reward stop-signal task resulted in participants displaying a faster MRT on go-trials on this task compared to on the Baseline task and on the Punishment task and a poorer go-trial response accuracy on the Reward task compared to on the other three tasks, and the specific rewarding and punishing stimuli present on the Conflict stop-signal task resulted in participants displaying a faster MRT on go-trials and a similar go-trial response accuracy on this task compared to on the Baseline task.

According to the race model, and as demonstrated in previous research, stopping becomes increasingly more difficult the later the stop-signal is presented in relation to the go-signal (e.g., Lappin & Eriksen, 1966; Logan, 1994; Logan & Cowan, 1984). Consistent with this and with previous research using the same stop-signal delays (Fillmore & Rush, 2002; Fillmore et al., 2001, 2002), probability of inhibition was found to decrease in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on all four tasks, in all 3 Experiments, in the present study. Negative slope functions were generated relating probability of inhibition to the stop-signal delays on each of the four tasks in Experiments 1, 2 and 3 (see figures 3.3, 3.7 and 3.12, respectively). The presence of these slopes not only provides verification of successful employment of appropriate delays but also that participants understood task requirements and correctly followed instructions. It is possible for stop-signal task performance to be affected by random response strategies and by inattention, owing to a lack of interest or motivation on the part of the participant (see Schachar et al., 1995; Tannock et al., 1995). The slope function can be used to detect such response styles. Randomly inhibiting and executing responses on stop-trials would generate a flat slope function since such a response strategy would result in inhibitions being equally likely to occur at all stop-signal delays. This was not observed on any of the four tasks in the present study. Rather, the negative slopes obtained demonstrate that response inhibition was under some degree of stimulus control of the stop-signals on all four tasks.

The results obtained in the present study indicate that inhibitory control and performance on the stop-signal task can be modified using different response contingencies. The idea that performance on the stop-signal task can be modified using rewarding/punishing stimuli could provide valuable information on how to moderate and explain inhibitory control in other situations (e.g., gambling behaviour). The present study was limited by small sample sizes in Experiments 1 and 2 and by the fact that it did not test for individual differences in inhibitory control and performance on the stop-signal task in the presence of different response contingencies. Modified inhibitory control and performance on the stop-signal task in the presence of specific rewarding/punishing stimuli could be further investigated and explained by looking at individual differences in reactions to reward and punishment. The use of the four tasks developed in the present study, along with a number of other viable behavioural tasks, to measure individual differences in reactions to reward and punishment is the subject of the next chapter.

# Chapter 4

# Experimental Study 4 (Part 1): Inhibitory Control and Personality on the Stop-signal Task and the Q-task

## 4.1 Aims and experimental predictions

### *4.1.1 Aims*

The aim of this study was to demonstrate that inhibitory control on the stop-signal task can be modified using different response contingencies and that these modifications should be related to individual differences in reward and punishment sensitivity (i.e., personality). Toward this end, the same four tasks used in Experiments 2 and 3 of chapter 3 (sections 3.2 and 3.3, respectively) were used to assess inhibitory control in the presence (and absence) of different specific motivational stimuli. The Q-task (described in chapter 2, section 2.1.2) was also included as a face valid, behavioural assessment device for the measurement of BIS functioning.

Participants' BIS, BAS and FFFS sensitivities were measured and analysed using the BIS/BAS Scales, the SPSRQ (designed to measure sensitivity to the BIS and the BAS with the Sensitivity to Punishment scale and the Sensitivity to Reward scale, respectively), the Y2 (trait) scale of the STAI (BIS measure), and the FSS (FFFS measure). The EPQ-RS was used to measure Extraversion and Neuroticism (as well as Psychoticism and the tendency to be untruthful). The PANAS was employed to gauge mood changes induced by task performance and the SOGS was also employed to measure gambling severity among participants. No previous research has investigated the influence of these four stop-signal task contingencies on inhibitory control and task performance within-subjects and the association of personality.

*4.1.2 Experimental predictions*

Based on previous research using the four stop-signal tasks (chapter 3, sections 3.2 and 3.3), it was predicted that dependent measures of task performance (probability of inhibition on stop-trials, SSRT, MRT on go-trials, and go-trial response accuracy) should differ across tasks in a similar manner as found in Experiment 3, chapter 3 (see section 3.3). In addition, based on arousal theory and Reinforcement Sensitivity Theory (RST), it was predicted that, since the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), higher self-reported BAS activity (i.e., scores on the Sensitivity to Reward scale of the SPSRQ, and the BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales) and Extraversion (E) should be associated with weaker inhibitory control on each of the four tasks and that, due to the presence of specific rewarding stimuli, these associations should be stronger on the Reward and Conflict tasks than on the Baseline and Punishment tasks. Conversely, higher self-reported BIS activity (i.e., scores on the BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, and the STAI), Fear (FSS score), and Neuroticism (N) should be associated with stronger inhibitory control on each of the four tasks and that, due to the presence of specific punishing stimuli, these associations should be stronger on the Punishment and Conflict tasks than on the Baseline and Reward tasks.

Since, according to the separable subsystems hypothesis, responses to reward should be the same at all levels of Anx and responses to punishment should be the same at all levels of Imp (see Corr, 2001, 2002b), it was also predicted that associations between BIS activity and measures of response inhibition should not differ when comparing the Reward task with the Baseline task or when comparing the Punishment task with the Conflict task and that associations between BAS activity and measures of response inhibition should not differ when comparing the Punishment task with the Baseline task or when comparing the Reward task with the Conflict task.

Based on previous research with the Q-task (e.g., Newman et al., 1997) it was predicted that higher self-reported BIS activity should be associated with greater Q-inhibition (the degree to which the Q elicits behavioural inhibition in the test phase).

## 4.2 Method

### *4.2.1 Participants*

Forty-two adult members of the general public (21 males, 21 females) participated. Participants' ages ranged between 18 and 53 years (mean = 25.02, S.D. = 8.68). They were recruited by means of opportunity sampling methods, and gave their written informed consent to take part in the study after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded £15 cash for their participation.

### *4.2.2 Materials*

Mood impacts?

#### *4.2.2.1 Personality measures*

Each of the personality measures employed (BIS/BAS Scales, SPSRQ, EPQ-RS, STAI Y2 scale, FSS, PANAS, and SOGS) are described in detail in chapter 2, section 2.2.

##### *4.2.2.1.1 Descriptive statistics*

Preliminary analyses revealed one case with an extremely high z score (beyond the $p = .001$ criterion of 3.29, two-tailed) on EPQ-RS Lie to be a univariate outlier. Since the Lie scale is designed for the revelation of dishonesty, the case with the extremely high Lie scale score was deleted from all analyses involving self-reported personality measures, leaving 41 cases for analysis. Means, standard deviations and correlations between measures are shown in Table 4.1. These data were similar to those reported in previous psychometric studies with larger samples (Jorm et al. 1999; Perkins, Kemp, & Corr, 2007; Stinchfield, 2002; Torrubia, Avila, Molto, & Caseras, 2001). Importantly, the BIS, Sensitivity to Punishment, STAI, Neuroticism, and FSS Fear scales were correlated as expected with one another and the BAS scales of the BIS/BAS Scales, Sensitivity to Reward, and Extraversion scales were correlated as expected with one another also (except that the Sensitivity to Reward scale of the SPSRQ was not positively correlated with the Extraversion scale of the EPQ-RS, contrary to expectations).

*4.2.2.2 Behavioural tasks*

The four stop-signal tasks (Baseline, Punishment, Reward, and Conflict) were the same as those used in Experiments 2 and 3 of chapter 3 and are described in detail in chapter 2, section 2.1.1. The Q-task is described in detail in chapter 2, section 2.1.2. The written Baseline, Punishment, Reward, Conflict and Q-task instructions given to participants are shown in full in Appendices A, E, F, G, and H, respectively.

*4.2.3 Design*

A repeated measures design was decided upon to best test the predictions. The advantage of this design was that fewer participants were needed and since the present study had no "surprise" element for participants a repeated measures design seemed most appropriate. Testing lasted approximately 2-hrs 30-mins per participant and was conducted in two separate sessions (each approximately 75-min duration) on two separate days (one session per day), at the same time of day (afternoon, between 12pm-5pm), with each participant. After completing the SOGS and a number of different personality questionnaires described in the materials section (section 4.2.2), participants were tested on four different types of computerised behavioural tasks: (1) the Q-task; (2) the slot machine simulations (see chapter 2, section 2.1.4 for description); (3) the CP tasks (see chapter 2, section 2.1.3 for description); and (4) the stop-signal tasks.

Table 4.1

*Means, Standard Deviations and Correlations between Personality Measures*

| | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | FSS | SOGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BD | — | | | | | | | | | | | | |
| BFS | .60** | — | | | | | | | | | | | |
| BRR | .37* | .32* | — | | | | | | | | | | |
| BIS | -.32* | -.22 | .16 | — | | | | | | | | | |
| SP | -.43** | -.39* | -.11 | .62** | — | | | | | | | | |
| SR | .22 | .35* | .34* | -.02 | .07 | — | | | | | | | |
| P | .34* | .45** | -.09 | -.34* | -.16 | .22 | — | | | | | | |
| E | .29 | .44** | .14 | -.38* | -.59** | .04 | .10 | — | | | | | |
| N | -.31 | -.13 | .09 | .67** | .77** | .12 | -.20 | -.34* | — | | | | |
| L | .14 | -.19 | .01 | .11 | -.10 | -.45** | -.17 | -.16 | -.18 | — | | | |
| STAI | -.30 | -.23 | -.05 | .64** | .77** | .05 | -.18 | -.41** | .83** | -.12 | — | | |
| FSS | -.37* | -.27 | -.03 | .42** | .54** | .01 | -.34* | -.04 | .39* | -.20 | .45** | — | |
| SOGS | -.08 | -.09 | -.11 | .13 | .12 | .22 | -.01 | -.15 | .09 | -.18 | .07 | .04 | — |
| Mean | 10.76 | 12.44 | 17.27 | 20.54 | 10.39 | 12.00 | 2.88 | 8.90 | 5.63 | 2.83 | 40.63 | 93.10 | 0.85 |
| SD | 2.18 | 2.58 | 2.10 | 3.74 | 6.02 | 4.09 | 1.60 | 3.21 | 3.59 | 2.02 | 11.35 | 51.35 | 0.91 |

*Note.* n = 41; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SR = Sensitivity to Reward; SP = Sensitivity to Punishment; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = Speilberger Trait Anxiety Inventory; FSS; Fear Survey Schedule; SOGS = South Oaks Gambling Screen.

*$p < .05$. **$p < .01$.

Each participant performed the stop-signal tasks last of all, in the second session, as they were the most time consuming, attention demanding and, therefore, the most likely to fatigue participants. The order of the Q-task, the slot machine simulations and the CP tasks was counterbalanced using a cyclic Latin-square (see Table 4.2). Participants were placed unknowingly and randomly into 3 sub-groups. Each sub-group performed the Q-Task, the slot machine simulations and the CP tasks in different orders to one another, according to the 'cyclic Latin-square' design. This design essentially ensured that the three behavioural tasks occurred equally frequently as the first and second tasks following completion of the personality questionnaires in the first session and as the first task prior to the stop-signal tasks in the second session. This is illustrated in Table 4.2. The cyclic Latin-square design also ensured that fatigue effects were counterbalanced across the computerised behavioural tasks.

Table 4.2

*Cyclic Latin-square Design used to Counterbalance the Order of Tasks across Participants*

| Sub-group | Order | | |
|---|---|---|---|
| | 1st in Session 1 | 2nd in Session 1 | 1st in Session 2 |
| 1 | Q-task | Slots | CP tasks |
| 2 | CP tasks | Q-task | Slots |
| 3 | Slots | CP tasks | Q-task |

*Note.* 1st in Session 1 = first task following completion of personality questionnaires in the first session; 2nd in Session 1 = second task following completion of personality questionnaires in the first session; 1st in Session 2 = first task prior to stop-signal tasks in the second session; Slots = slot machine simulations.

The order of the personality measures was kept the same across all participants. Each participant completed them in the following, consecutive, order: (1) SOGS; (2) STAI; (3) FSS; (4) EPQ-RS; (5) BIS/BAS Scales; (6) SPSRQ; and (7) PANAS. The order of stop-signal task administration was the same as in Experiments 1, 2 and 3 of chapter 3 (see section 3.1.2.2.2).

*4.2.4 Procedure*

Two separate sessions (each approximately 75-min duration) were conducted on two separate days (one session per day), at the same time of day (afternoon, between 12pm-5pm), with each participant. On arrival at the laboratory for the first session the participant was seated and instructed to read the information sheet (the details of which are shown below) and to ask for a consent form when finished if they wished to continue. The information sheet informed the participant that the first session of the present study involved completing a number of personality tests in the form of questionnaires and performing a series of tasks presented on a computer. It informed the participant that the second session of the present study involved performing a further series of tasks presented on a computer. The information sheet also explained how written instructions of how to complete each individual questionnaire and perform each computer task would be provided. It also assured the participant that they were free to withdraw from the study at any point without penalty, that they could request a break at any time, that all results would be anonymised and that it would not be possible to identify individual participant's data. If the participant wished to continue having read the information sheet they were instructed to complete the written consent form. The completed consent form was kept separately from all other data in order to ensure the confidentiality and anonymity of the participant's results.

Having obtained informed consent, the personality questionnaires described in the materials section (section 4.2.2) were administered to the participant in the order described in the design section (section 4.2.3). The participant was instructed to follow the written instructions provided at the beginning of each individual questionnaire and to complete them as quickly as possible. On completion of the questionnaires, a series of computer tasks were administered to the participant: the Q-task followed by the slot machine simulations; the CP tasks followed by the Q-task; or the slot machine simulations followed by the CP tasks, (depending on which sub-group the participant was assigned to according to the cyclic Latin-square described in the design section; section 4.2.3). On completion of each individual computer task administered in the first session, a PANAS was administered to the participant and only on completion of the PANAS was the next computer task administered. The participant was instructed to follow the written instructions provided at the beginning of each computer task.

On arrival at the laboratory for the second session the participant was seated and instructed to complete a PANAS. The participant was then administered either the CP tasks, the slot machine simulations or the Q-task (depending on which sub-group the participant was assigned to according to the cyclic Latin-square described in the design section above; section 4.2.3) followed by the four stop-signal tasks. On completion of each individual computer task administered in the second session, a PANAS was administered to the participant and only on completion of the PANAS was the next computer task administered. The order in which the four stop-signal tasks were administered is described in the materials section (section 4.2.2). The participant was instructed to follow the written instructions provided at the beginning of each computer task. Participants were debriefed on completion of the final PANAS following completion of the final stop-signal task (the Conflict task), thanked and awarded £15 cash for their participation. They were again assured that all the information they provided would remain confidential to the study and that the information they provided would be used to investigate the influence of personality on gambling behaviour - in particular, connections between reinforcement sensitivity theory and inhibitory control. The data collected and saved from each of the computer tasks for each of the forty-two participants had to be individually recorded and analysed in spreadsheets.

### *4.2.5 Dependent measures and data analyses of behavioural task performance*

#### *4.2.5.1 Dependent measures of stop-signal task performance*

See chapter 2, section 2.1.1.5, for detailed descriptions of dependent measures of response inhibition (probability of inhibition on stop-trials and stop-signal reaction time), response execution (go-trial reaction time and go-trial response accuracy) and methods for assessing these dependent measures for each participant on each task.

*4.2.5.2 Dependent measure of Q-task performance*

The dependent measure of interest on the Q-task is Q-inhibition. Q-inhibition is a measurement of the degree to which the Q elicits behavioural inhibition in the test phase of the Q-task. See chapter 2, section 2.1.2.1, for a detailed description of the method for assessing this dependent measure for each participant.

*4.2.5.3 Data analyses of stop-signal task performance*

*4.2.5.3.1 Confirmatory analyses*

*4.2.5.3.1.1 Order effects*

Effects of the counterbalancing variable Order on the four dependent measures of stop-signal task performance across Task were analysed by mixed multivariate analysis of variance (MANOVA) with Order (Punishment task before Reward task or Reward task before Punishment task) as the between-subjects factor. Adjustment was made for four covariates: baseline probability of inhibition on stop-trials, baseline SSRT, baseline MRT on go-trials and baseline go-trial response accuracy. Baseline task performance measures were included as covariates to assess the effect of Order on task performance measures after adjusting for initial differences in stop-signal task performance. The within-subjects factor treated multivariately was the three Tasks performed after the Baseline task: the Punishment, Reward, and Conflict tasks. There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy).

$N = 21$ for both Orders. There was no significant main effect of Order, $F(4, 33) = 0.71, p > .05$; Wilks' Lambda = .92, and no significant interaction between Order and Task, $F(8, 29) = 0.90$, $p > .05$; Wilks' Lambda = .80. Since none of the main effects or interactions involving Order was significant, data were collapsed for subsequent analyses.

*4.2.5.3.1.2 Task effects*

Task effects on the four dependent measures of stop-signal task performance (the two criterion measures of response inhibition: probability of inhibition on stop-trials and SSRT; and the two criterion measures of response execution: MRT on go-trials and go-trial response accuracy) were analysed by mixed multivariate analysis of variance (MANOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor treated multivariately. Sex (male or female) was included as the between-subjects factor to assess the effect of gender on the four dependent measures of task performance. Follow-up repeated measure ANOVAs generated by the overall mixed MANOVA were used to analyse each individual dependent measure of task performance across Task. Specific hypotheses concerning task differences in response inhibition and response execution between individual tasks were tested using simple within-subjects contrasts.

*4.2.5.3.1.3 Effects of stop-signal delay on probability of inhibition*

Effects of stop-signal delay on probability of inhibition on stop-trials were analysed by separate one-way repeated measure analyses of variance (ANOVA) with Delay (50, 150, 250 and 350-ms) as the within-subjects factor. Polynomial within-subjects contrasts were used to test the hypotheses that probability of inhibition should decrease in a linear fashion across the four stop-signal delays, from 50 to 350-ms, on each stop-signal task.

*4.2.5.3.1.4 Personality*

In order to assess whether personality was associated with response inhibition and performance on the stop-signal tasks, Pearson correlations were calculated between the four dependent measures of task performance (the two criterion measures of response inhibition: probability of inhibition on stop-trials and SSRT; and the two criterion measures of response execution: MRT on go-trials and go-trial response accuracy) for all four tasks, on the one hand, and the personality measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, BIS, SP, SR, P, E, N, L, STAI, Fear, and SOGS score), on the other hand. Pearson correlations were also calculated between the four dependent measures of task performance for all four tasks, on the one hand, and age and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and stop-signal task performance.

*4.2.5.3.1.5 Task differences on associations between personality and response inhibition*

The combination of the categorical variable Task and the continuous variable Personality as predictors of the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT), was analysed by separate one-way repeated measure analyses of covariance (ANCOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor. Covariates were the subscales of the BIS/BAS Scales (BAS Drive, BAS Fun Seeking, BAS Reward Responsiveness, and BIS; in one ANCOVA), subscales of the SPSRQ (SP and SR; in one ANCOVA), subscales of the EPQ-RS (P, E, N, and L; in one ANCOVA), the STAI (in one ANCOVA), and FSS Fear (in one ANCOVA). Specific hypotheses concerning task differences on associations between personality and response inhibition between individual tasks were tested using simple within-subjects contrasts.

*4.2.5.3.2 Exploratory analyses*

*4.2.5.3.2.1 Personality and affect following stop-signal task performance*

Self-reported positive and negative affect scores, measured on the PANAS following performance of each of the four tasks, were investigated in an attempt to make sense of some of the unexpected findings revealed concerning associations between personality and response inhibition on and across the tasks. Associations between personality and positive and negative affect following performance of the four stop-signal tasks were investigated using Pearson correlations, calculated between the two dependent measures of affect (positive and negative) following all four tasks, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the two dependent measures of affect following all four tasks, on the one hand, and age and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and affect following task performance.

*4.2.5.3.2.2 Task order and associations between personality and response inhibition*

Associations between response inhibition and personality were analysed separately for the two groups that performed the stop-signal tasks in different orders (Punishment task before Reward task or Reward task before Punishment task) to investigate further the unexpected findings revealed concerning associations between personality and response inhibition on and across the tasks. Pearson correlations were calculated between the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) for the three tasks performed in different orders after the Baseline task (Punishment, Reward and Conflict), on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the two dependent measures of response inhibition for these three tasks, on the one hand, and age and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and response inhibition.

*4.2.5.3.2.3 Sex and associations between personality and response inhibition*

Associations between response inhibition and personality were analysed separately for sex (male and female) to investigate even further the unexpected findings revealed concerning associations between personality and response inhibition on and across the tasks. Pearson correlations were calculated between the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) for all four tasks, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the two dependent measures of response inhibition for all four tasks, on the one hand, and age, on the other hand, in order to investigate any associations between age and response inhibition.

*4.2.5.4 Data analyses of Q-task performance*

In order to assess whether personality was associated with Q-task performance, Pearson correlations were calculated between the dependent measure of task performance (Q-inhibition), on the one hand, and the personality measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, BIS, SP, SR, P, E, N, L, STAI, Fear, and SOGS score), on the other hand. Pearson correlations were also calculated between Q-inhibition, on the one hand, and age, and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and Q-task performance.

*4.2.5.5 Exploratory analyses*

Pearson correlations were calculated between the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) on all four stop-signal tasks and Q-inhibition to investigate associations between inhibition measures on and between experimental tasks.

## 4.3 Results

### *4.3.1 Stop-signal tasks*

#### *4.3.1.1 Task effects on stop-signal task performance*

There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy). $N = 42$: 21 males; 21 females. Means and standard deviations of stop-signal task performance measures across the four tasks are shown in Table 4.3.

Mixed MANOVA revealed significant multivariate effects for the main effect of Task on the four dependent measures of stop-signal task performance, $F(12, 29) = 29.14$, $p < .01$; Wilks' Lambda = .08. Follow-up ANOVAs revealed that the four tasks differed in terms of probability of inhibition on stop-trials, $F(3, 120) = 27.22$, $p < .01$, SSRT, $F(3, 120) = 6.40$, $p < .01$, MRT on go-trials (Greenhouse-Geisser correction), $F(2.39, 95.56) = 61.64$, $p < .01$, and go-trial response accuracy, $F(3, 120) = 12.19$, $p < .01$. This indicates that, consistent with prediction, mean measures of response inhibition (probability of inhibition on stop-trials and SSRT) and mean measures of response execution (MRT on go-trials and go-trial response accuracy) differed across the four tasks with different response contingencies. There was no significant main effect of Sex, $F(1, 37) = 1.45$, $p > .05$; Wilks' Lambda = .87, and no significant interaction between Sex and Task, $F(12, 29) = 0.67$, $p > .05$; Wilks' Lambda = .78. Since none of the main effects or interactions involving Sex was significant, data were collapsed for subsequent analyses.

Table 4.3

*Mean and Standard Deviation of Stop-signal Task Performance Measures across the Four Tasks*

| Measure | Stop-signal Task | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | Punishment | | Reward | | Conflict | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *P* (Inhibition) | 0.60 | 0.16 | 0.66 | 0.14 | 0.49 | 0.16 | 0.56 | 0.15 |
| SSRT (msec) | 282 | 61.37 | 240 | 49.02 | 273 | 63.37 | 263 | 65.81 |
| MRT (msec) | 521 | 59.32 | 509 | 63.30 | 459 | 51.05 | 473 | 47.97 |
| No. of errors | 8.36 | 5.81 | 6.26 | 4.75 | 10.40 | 5.95 | 8.12 | 5.81 |

*Note.* n = 42; *P* (Inhibition) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; No. of errors = number of response errors made on go-trials.

*4.3.1.1.1 Response inhibition*

*4.3.1.1.1.1 Probability of inhibition on stop-trials*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Punishment task and probability of inhibition on stop-trials on the Baseline task, $F(1, 41) = 12.55$, $p < .01$, the Reward task, $F(1, 41) = 70.15$, $p < .01$, and on the Conflict task, $F(1, 41) = 34.47$, $p < .01$. Mean probability of inhibition on stop-trials across the four stop-signal tasks is shown in Figure 4.1. Examination of Figure 4.1 indicates that, as predicted, probability of inhibition on stop-trials was higher (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, higher on the Punishment task than on the Reward task and higher on the Punishment task than on the Conflict task.

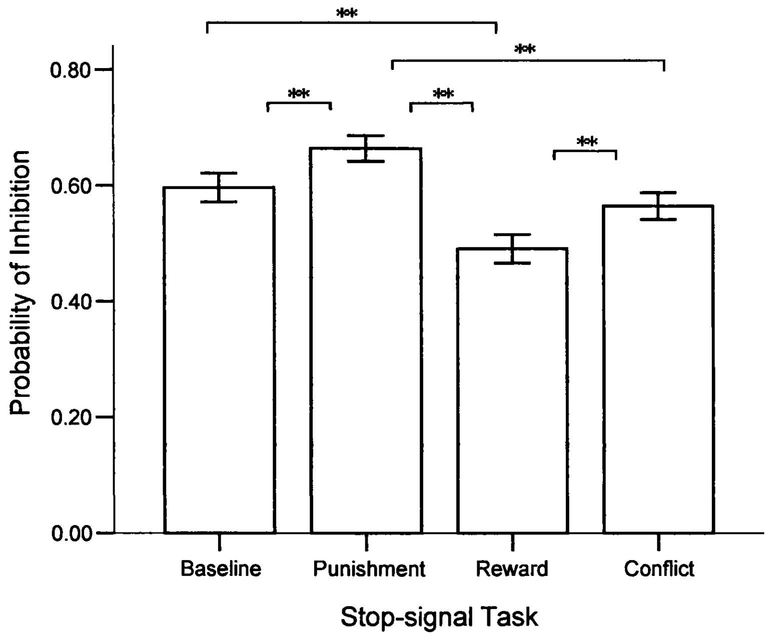


*Figure 4.1.* Mean probability of inhibition on stop-trials ( ± 1 SE) for Baseline (n = 42), Punishment (n = 42), Reward (n = 42), and Conflict (n = 42) stop-signal tasks.

$^{**}p < .01$.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between probability of inhibition on stop-trials on the Reward task and probability of inhibition on stop-trials on the Baseline task, $F(1, 41) = 26.40, p < .01$, and on the Conflict task, $F(1, 41) = 18.06, p < .01$. Examination of Figure 4.1 indicates that, as predicted, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Reward task than on the Baseline task and lower on the Reward task than on the Conflict task. Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between probability of inhibition on stop-trials on the Conflict task and probability of inhibition on stop-trials on the Baseline task, $F(1, 41) = 2.12, p > .05$.

*4.3.1.1.1.2 Stop-signal reaction time (SSRT)*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between SSRT on the Punishment task and SSRT on the Baseline task, $F(1, 41) = 27.34, p < .01$, the Reward task, $F(1, 41) = 9.65, p < .01$, and on the Conflict task, $F(1, 41) = 6.21, p < .05$. Mean SSRT across the four stop-signal tasks is shown in Figure 4.2. Examination of Figure 4.2 indicates that, as predicted, SSRT was faster (i.e., inhibitory control was stronger) on the Punishment task than on the Baseline task, faster on the Punishment task than on the Reward task and faster on the Punishment task than on the Conflict task.

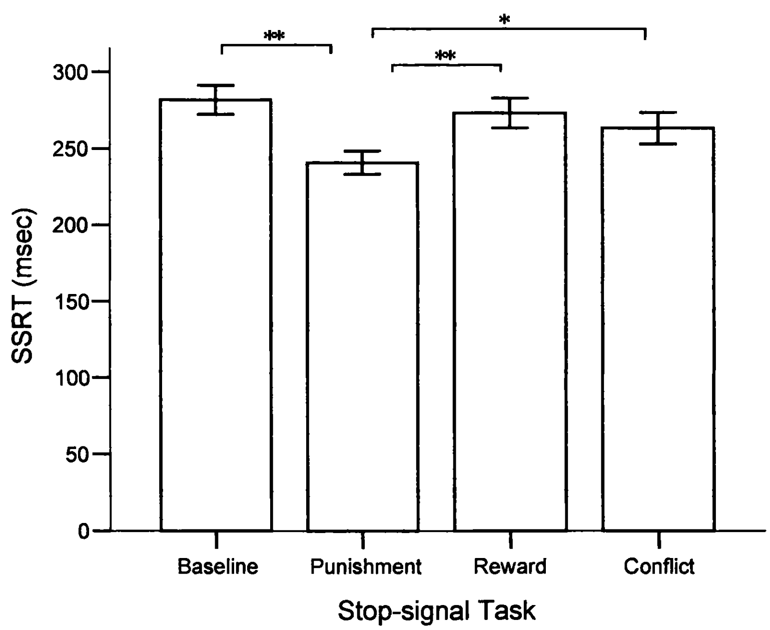


*Figure 4.2.* Mean stop-signal reaction time (SSRT) ( ± 1 SE) for Baseline (n = 42), Punishment (n = 42), Reward (n = 42), and Conflict (n = 42) stop-signal tasks.

*$p < .05$. **$p < .01$.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed, contrary to prediction, no significant mean difference between SSRT on the Reward task and SSRT on the Baseline task, $F(1, 41) = 0.68, p > .05$, or on the Conflict task, $F(1, 41) = 0.87$,

$p > .05$. Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between SSRT on the Conflict task and SSRT on the Baseline task, $F(1, 41) = 3.44, p > .05$.

*4.3.1.1.2 Response execution*

*4.3.1.1.2.1 Mean reaction time (MRT) on go-trials*

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between MRT on go-trials on the Reward task and MRT on go-trials on the Baseline task, $F(1, 41) = 161.87, p < .01$, the Punishment task, $F(1, 41) = 92.91$, $p < .01$, and on the Conflict task, $F(1, 41) = 14.68, p < .01$. Mean MRT on go-trials across the four stop-signal tasks is shown in Figure 4.3. Examination of Figure 4.3 indicates that MRT on go-trials was faster on the Reward task than on the Conflict task and, as predicted, MRT on go-trials was faster on the Reward task than on the Baseline task and faster on the Reward task than on the Punishment task.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed significant mean differences between MRT on go-trials on the Conflict task and MRT on go-trials on the Baseline task, $F(1, 41) = 76.86, p < .01$, and on the Punishment task, $F(1, 41) = 41.98, p < .01$. Examination of Figure 4.3 indicates that, as predicted, MRT on go-trials was faster on the Conflict task than on the Baseline task and faster on the Conflict task than on the Punishment task. Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed no significant mean difference between MRT on go-trials on the Punishment task and MRT on go-trials on the Baseline task, $F(1, 41) = 3.25, p > .05$.

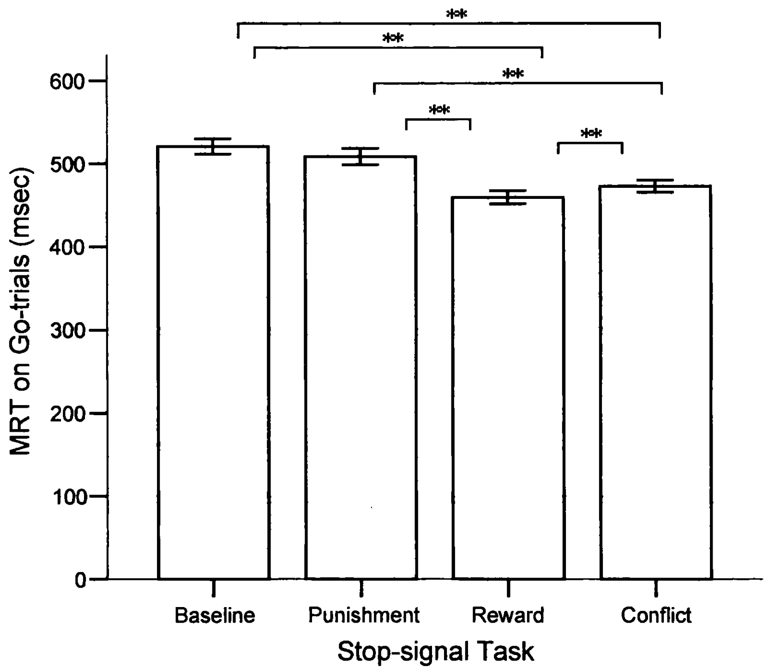


*Figure 4.3.* Mean reaction time (MRT) on go-trials ( ± 1 SE) for Baseline (n = 42), Punishment (n = 42), Reward (n = 42), and Conflict (n = 42) stop-signal tasks.

**$p < .01$.

*4.3.1.1.2.2 Go-trial response accuracy*

Simple within-subjects contrasts with the Punishment stop-signal task selected as the reference category revealed significant mean differences between the number of response errors made on go-trials on the Punishment task and the number of response errors made on go-trials on the Baseline task, $F(1, 41) = 11.19, p < .01$, Reward task, $F(1, 41) = 30.06, p < .01$, and on the Conflict task, $F(1, 41) = 8.88, p < .01$. Mean number of response errors made on go-trials across the four stop-signal tasks is shown in Figure 4.4. Examination of Figure 4.4 indicates that, as predicted, the number of response errors made on go-trials was fewer (i.e., go-trial response accuracy was greater) on the Punishment task than on the Baseline task, fewer on the Punishment task than on the Reward task and fewer on the Punishment task than on the Conflict task.

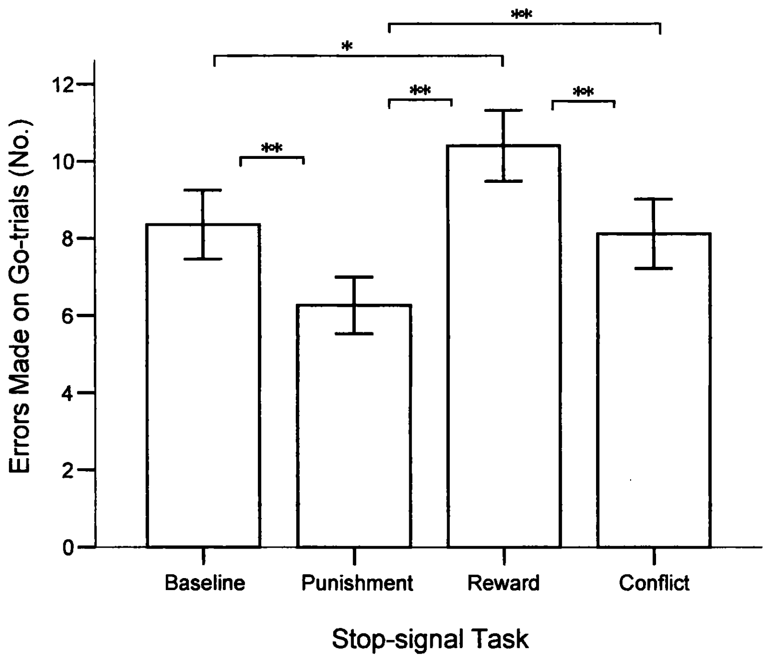


*Figure 4.4.* Mean number of response errors made on go-trials ( ± 1 SE) for Baseline (n = 42), Punishment (n = 42), Reward (n = 42), and Conflict (n = 42) stop-signal tasks.

$*p < .05$. $**p < .01$.

Simple within-subjects contrasts with the Reward stop-signal task selected as the reference category revealed significant mean differences between the number of response errors made on go-trials on the Reward task and the number of response errors made on go-trials on the Baseline task, $F(1, 41) = 6.54, p < .05$, and on the Conflict task, $F(1, 41) = 12.31, p < .01$. Examination of Figure 4.4 indicates that, as predicted, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Reward task than on the Baseline task and greater on the Reward task than on the Conflict task. Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, consistent with prediction, no significant mean difference between the number of response errors made on go-trials on the Conflict task and the number of response errors made on go-trials on the Baseline task, $F(1, 41) = 0.15, p > .05$.

#### *4.3.1.2 Effects of stop-signal delay on probability of inhibition*

ANOVA revealed a significant main effect of Delay on probability of inhibition on stop-trials on the Baseline (Greenhouse-Geisser correction), $F(2.39, 98.00) = 249.50, p < .01$, Punishment (Greenhouse-Geisser correction), $F(2.24, 91.66) = 225.97, p < .01$, Reward (Greenhouse-Geisser correction), $F(2.58, 105.90) = 230.96, p < .01$, and Conflict, $F(3, 123) = 267.38, p < .01$, tasks. Figure 4.5 plots mean probability of inhibition at each stop-signal delay on each of the four stop-signal tasks. Figure 4.5 indicates that, as expected, probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay. This function was evident on all four tasks and polynomial within-subjects contrasts revealed these functions to be significant linear trends on the Baseline, $F(1, 41) = 478.62, p < .01$, Punishment, $F(1, 41) = 446.04, p < .01$, Reward, $F(1, 41) = 729.91, p < .01$, and Conflict, $F(1, 41) = 838.51, p < .01$, tasks. This indicates that, as predicted, probability of inhibition decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each on the four stop-signal tasks.

#### *4.3.1.3 Personality and stop-signal task performance*

Table 4.4 shows correlations between dependent measures of stop-signal task performance on the four tasks and personality measures. There were no significant associations between age or sex and the four dependent measures of task performance on any of the four tasks, $p > .05$.

##### *4.3.1.3.1 Response inhibition*

As expected, significant correlations were obtained for measures of response inhibition (probability of inhibition on stop-trials and SSRT) on the Reward stop-signal task and measures of BIS activity. However, contrary to prediction, a higher score on the Sensitivity to Punishment scale and a higher score on the STAI were related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $r(41) = -.42, p < .01$, and, $r(41) = -.31, p < .05$, respectively.

Also contrary to prediction, a higher score on the Sensitivity to Punishment scale and a higher score on the STAI were related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $r(41) = .53, p < .01$, and, $r(41) = .50, p < .05$, respectively. However, these significant correlations were only obtained for the Reward task. Contrary to prediction, no measure of BIS activity (BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, STAI trait anxiety) was significantly related to the two measures of response inhibition (probability of inhibition on stop-trials and SSRT) on the Baseline, Punishment, or Conflict tasks, $p > .05$.

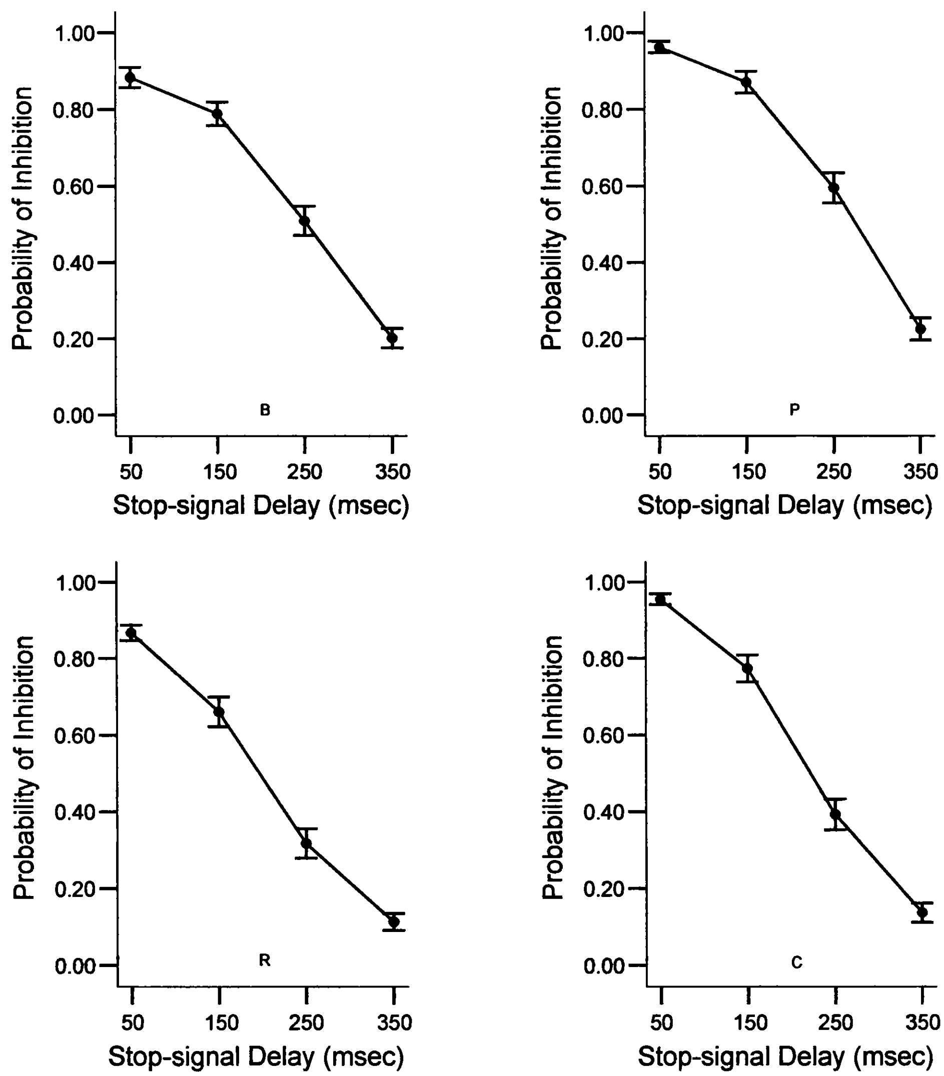


*Figure 4.5.* Mean probability of inhibition at each stop-signal delay ( ± 1 SE) on the Baseline (panel B), Punishment (panel P), Reward (panel R) and Conflict (panel C) stop-signal tasks.

Table 4.4

*Correlations between Stop-signal Task Performance Measures on the Four Tasks and Personality Measures, Age, and Sex*

| Task | Measure | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | *P* (In) | .18 | .05 | .06 | -.05 | -.04 | -.03 | .22 | .00 | -.11 | -.13 | .03 | .04 | -.14 | .27 | .08 |
| | SSRT | -.11 | -.13 | -.09 | -.04 | -.04 | .12 | -.13 | .04 | .00 | .02 | -.14 | .00 | .33* | -.06 | -.06 |
| | MRT | .10 | -.08 | .00 | -.10 | -.03 | .13 | .06 | .01 | -.07 | -.20 | -.07 | .08 | .21 | .28 | .13 |
| | Errors | -.09 | -.09 | -.18 | .10 | .31 | .17 | -.14 | -.02 | .41** | -.14 | .32* | .24 | .21 | -.11 | .07 |
| Punishment | *P* (In) | .19 | .13 | .08 | .05 | .06 | .21 | .18 | .09 | .12 | -.21 | .19 | .06 | .05 | .13 | -.13 |
| | SSRT | -.11 | -.21 | -.20 | -.20 | -.10 | -.16 | .03 | -.06 | -.14 | -.15 | -.17 | -.02 | .13 | -.01 | -.01 |
| | MRT | .09 | -.09 | -.08 | -.04 | .04 | .13 | .12 | .03 | .09 | -.31 | .12 | .13 | .23 | .13 | -.04 |
| | Errors | -.22 | -.11 | -.05 | .08 | .16 | .15 | -.21 | -.14 | .25 | -.12 | .12 | .04 | .29 | .04 | .05 |
| Reward | *P* (In) | .29 | .19 | .00 | -.26 | -.42** | .11 | .21 | .32* | -.30 | -.03 | -.31* | -.22 | -.08 | .24 | -.12 |
| | SSRT | -.29 | -.24 | .16 | .25 | .53** | .22 | -.16 | -.36* | .45** | -.21 | .50** | .35* | .25 | .06 | -.07 |
| | MRT | .15 | -.05 | -.02 | -.18 | -.15 | .21 | .10 | .14 | -.09 | -.27 | -.10 | .01 | .17 | .22 | -.10 |
| | Errors | -.11 | -.20 | -.11 | -.06 | .26 | -.06 | -.16 | -.21 | .24 | -.05 | .08 | .06 | .18 | -.20 | .11 |
| Conflict | *P* (In) | .17 | .15 | .02 | .07 | -.17 | .10 | .24 | .15 | -.01 | -.07 | -.05 | -.12 | -.06 | .11 | -.14 |
| | SSRT | -.05 | -.28 | -.05 | -.05 | .25 | -.02 | -.18 | -.21 | .07 | .14 | .14 | .22 | .28 | .03 | -.03 |
| | MRT | .15 | -.06 | -.02 | -.06 | -.09 | .13 | .11 | .00 | -.01 | -.13 | -.08 | -.03 | .29 | .14 | -.07 |
| | Errors | -.22 | -.08 | -.20 | -.08 | .18 | .05 | -.14 | -.04 | .22 | -.21 | .12 | .02 | .20 | -.18 | .15 |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; Errors = number of response errors made on go-trials; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

*$p < .05$. **$p < .01$.

Examination of Table 4.4 shows that, as expected, significant correlations were obtained for SSRT on the Reward stop-signal task and measures of Extraversion and Neuroticism. However, contrary to prediction, a higher score on the Neuroticism scale and a lower score on the Extraversion scale were related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $r(41) = .45, p < .01$, and, $r(41) = -.36, p < .05$, respectively. A significant correlation was obtained for the other measure of response inhibition, probability of inhibition on stop-trials, on the Reward task and Extraversion and a near significant correlation was obtained for probability of inhibition on stop-trials on the Reward task and Neuroticism. Again, contrary to prediction, a higher score on the Neuroticism scale and a lower score on the Extraversion scale were related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $r(41) = -.30, p = .06$, and, $r(41) = .32$, $p < .05$, respectively. However, these significant (and near significant) correlations were only obtained for the Reward task. Contrary to prediction, the Extraversion scale and the Neuroticism scale of the EPQ-RS were not significantly related to the two measures of response inhibition (probability of inhibition on stop-trials and SSRT) on the Baseline, Punishment, or Conflict tasks, $p > .05$.

As expected, a significant correlation was obtained for SSRT on the Reward stop-signal task and the measure of Fear. However, contrary to prediction, a higher Fear score was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $r(41) = .35, p < .05$. This finding was not supported by a significant correlation between the other measure of response inhibition, probability of inhibition on stop-trials, on the Reward task and Fear, $r(41) = -.22, p > .05$. Also contrary to prediction, FSS Fear was not significantly related to the two measures of response inhibition on the Baseline, Punishment, or Conflict tasks, $p > .05$.

Near significant correlations were obtained for measures of response inhibition on the Reward task and a measure of BAS activity. However, contrary to prediction, a higher score on the BAS Drive scale was related to a higher probability of inhibition on stop-trials, $r(41) = .29, p = .07$, and a faster SSRT, $r(41) = -.29, p = .07$, (i.e., stronger inhibitory control) on the Reward task. A near significant correlation was obtained for SSRT on the Conflict task and a measure of BAS activity. Contrary to prediction, a higher score on the BAS Fun Seeking scale was related to a faster SSRT (i.e., stronger inhibitory control) on the Conflict task, $r(41) = -.28$, $p = .08$. However, this finding was not supported by a significant correlation between the other measure of response inhibition, probability of inhibition on stop-trials, on the Conflict task and score on the BAS Fun Seeking scale, $r(41) = .15$, $p > .05$. Contrary to prediction, the Sensitivity to Reward scale of the SPSRQ, the BAS Fun Seeking and the BAS Reward Responsiveness scales of the BIS/BAS Scales were not significantly related to the two measures of response inhibition on the Reward task, $p > .05$, and the Sensitivity to Reward scale, the BAS Drive scale and the BAS Reward Responsiveness scale were not significantly related to the two measures of response inhibition on the Conflict task, $p > .05$. Also contrary to prediction, no measure of BAS activity (Sensitivity to Reward scale of the SPSRQ, BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales) was significantly related to the two measures of response inhibition on the Baseline or Punishment tasks, $p > .05$.

A significant correlation was revealed for SSRT on the Baseline stop-signal task and SOGS score, $r(41) = .33$, $p < .05$, and a near significant correlation was revealed for SSRT on the Conflict task and SOGS score, $r(41) = .28$, $p = .08$. The positive sign of these correlations relates to a higher score on the SOGS being associated with a slower SSRT (i.e., weaker inhibitory control) on the Baseline and Conflict tasks. However, these findings were not supported by a significant correlation between the other measure of response inhibition, probability of inhibition on stop-trials, on the Baseline and Conflict tasks and SOGS score, $r(41) = -.14$, $p > .05$, and, $r(41) = -.06$, $p > .05$, respectively.

*4.3.1.3.2 Response execution*

Examination of Table 4.4 shows that a higher score on the Neuroticism scale and a higher score on the STAI (i.e., BIS) were related to a greater number of response errors made on go-trials (i.e., poorer go-trial response accuracy) on the Baseline task, $r(41) = .41$, $p < .01$, and, $r(41) = .32$, $p < .05$, respectively. A higher score on the Sensitivity to Punishment (i.e., BIS) scale was near significantly related to a greater number of response errors made on go-trials (i.e., poorer go-trial response accuracy) on the Baseline task, $r(41) = .31, p = .05$, and the Reward task, $r(41) = .26, p = .10$. No other associations between personality measures and measures of response execution (MRT on go-trials and go-trial response accuracy) on the four tasks were significant, $p > .05$.

*4.3.1.4 Task differences on associations between personality and response inhibition*

*4.3.1.4.1 BIS/BAS Scales*

*4.3.1.4.1.1 Probability of inhibition on stop-trials*

ANCOVA revealed a near significant interaction between Task and BIS, $F(3, 108) = 2.12, p = .10$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BIS differed according to Task. There was no significant interaction between Task and BAS Drive, $F(3, 108) = 0.06, p > .05$, Task and BAS Fun Seeking, $F(3, 108) = 0.43, p > .05$, or between Task and BAS Reward Responsiveness, $F(3, 108) = 0.24, p > .05$. The results of the simple within-subjects contrasts are summarised in Table 4.5.

Examination of Table 4.5 shows that simple within-subjects contrasts with the Conflict task selected as the reference category revealed a significant interaction between Task and BIS when comparing the Conflict task with the Reward task, $F(1, 36) = 7.84, p < .01$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BIS differed according to Task when comparing these two tasks. Figure 4.6 displays the correlation between probability of inhibition on stop-trials and BIS on the four stop-signal tasks. The regression lines in panels R and C of Figure 4.6 indicate that, although, in general, contrary to prediction, there was a moderate trend toward a higher score on the BIS scale being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, there was a slight trend toward the opposite, predicted, association on the Conflict task.

Table 4.5

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and BIS/BAS Scales when Comparing Individual Tasks for Probability of Inhibition on Stop-trials*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × BAS Drive | *P* (In) | Reward | R vs. B | 1 | 0.01 | .92 |
| | | | R vs. P | 1 | 0.13 | .72 |
| | | | R vs. C | 1 | 0.15 | .70 |
| | | Conflict | C vs. B | 1 | 0.04 | .85 |
| | | | C vs. P | 1 | 0.00 | .95 |
| | | Punishment | P vs. B | 1 | 0.07 | .79 |
| Error | | | | 36 | | |
| Task × BAS Fun Seeking | *P* (In) | Reward | R vs. B | 1 | 0.40 | .53 |
| | | | R vs. P | 1 | 0.01 | .91 |
| | | | R vs. C | 1 | 0.26 | .62 |
| | | Conflict | C vs. B | 1 | 0.94 | .34 |
| | | | C vs. P | 1 | 0.11 | .75 |
| | | Punishment | P vs. B | 1 | 0.67 | .42 |
| Error | | | | 36 | | |
| Task × BAS Reward Responsiveness | *P* (In) | Reward | R vs. B | 1 | 0.25 | .62 |
| | | | R vs. P | 1 | 0.09 | .76 |
| | | | R vs. C | 1 | 0.09 | .76 |
| | | Conflict | C vs. B | 1 | 0.49 | .49 |
| | | | C vs. P | 1 | 0.38 | .54 |
| | | Punishment | P vs. B | 1 | 0.05 | .82 |
| Error | | | | 36 | | |
| Task × BIS | *P* (In) | Punishment | P vs. B | 1 | 0.64 | .43 |
| | | | P vs. R | 1 | 3.65 | .06 |
| | | | P vs. C | 1 | 0.14 | .72 |
| | | Conflict | C vs. B | 1 | 0.97 | .33 |
| | | | C vs. R | 1 | 7.84** | .01 |
| | | Reward | R vs. B | 1 | 1.25 | .27 |
| Error | | | | 36 | | |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

$^{**}p < .01$.

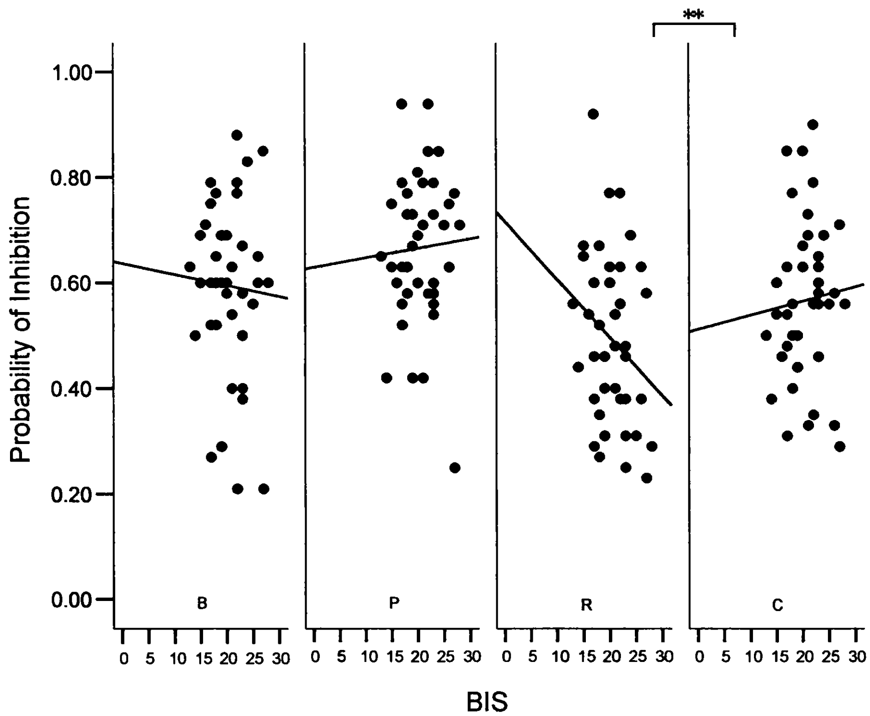


*Figure 4.6.* BIS scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

**$p < .01$.

Contrary to prediction, no other Task × BIS or Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$. Simple within-subjects contrasts with the Punishment task selected as the reference category revealed a near significant interaction between Task and BIS when comparing the Punishment task with the Reward task, $F(1, 36) = 3.65$, $p = .06$. This suggests that, as expected, the response of probability of inhibition to BIS differed according to Task when comparing these two tasks. The regression lines in panels R and P of Figure 4.6 indicate that, although, in general, contrary to prediction, there was a moderate trend toward a higher score on the BIS scale being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, there was a slight trend toward the opposite, predicted, association on the Punishment task.

Table 4.5 shows that, as expected, there was no significant interaction between Task and BIS when comparing the Punishment task with the Conflict task, $p > .05$. This suggests that, as predicted, the response of probability of inhibition on stop-trials to BIS (as measured by this scale) did not differ between these two tasks. Also consistent with prediction, there was no significant interaction between Task and BAS measures (Drive, Fun Seeking, Reward Responsiveness) when comparing the Punishment task with the Baseline task, $p > .05$. There was no significant interaction between Task and BIS when comparing the Punishment task with the Baseline task, $p > .05$, contrary to prediction. Simple within-subjects contrasts with the Reward task selected as the reference category revealed, consistent with prediction, no significant interaction between Task and BIS when comparing the Reward task with the Baseline task, $p > .05$, and no significant interaction between Task and BAS measures (Drive, Fun Seeking, Reward Responsiveness) when comparing the Reward task with the Conflict task, $p > .05$, (see Table 4.5). Contrary to prediction, no other Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction, revealed by simple within-subjects contrasts with the Reward task selected as the reference category, was significant, $p > .05$.

*4.3.1.4.1.2 Stop-signal reaction time (SSRT)*

ANCOVA revealed no significant interaction between Task and BAS Drive, $F(3, 108) = 1.50$, $p > .05$, Task and BAS Fun Seeking, $F(3, 108) = 1.10$, $p > .05$, Task and BAS Reward Responsiveness, $F(3, 108) = 1.63$, $p > .05$, or between Task and BIS, $F(3, 108) = 0.81$, $p > .05$. The results of the simple within-subjects contrasts are summarised in Table 4.6. Examination of Table 4.6 shows that simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and BAS Drive when comparing the Reward task with the Conflict task, $F(1, 36) = 4.19$, $p < .05$. This suggests that, contrary to prediction, the response of SSRT to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.7 displays the correlation between SSRT and BAS Drive on the four stop-signal tasks.

Table 4.6

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and BIS/BAS Scales when Comparing Individual Tasks for Stop-signal Reaction Time (SSRT)*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × BAS Drive | SSRT | Reward | R vs. B | 1 | 0.99 | .33 |
| | | | R vs. P | 1 | 1.63 | .21 |
| | | | R vs. C | 1 | 4.19* | .05 |
| | | Conflict | C vs. B | 1 | 0.94 | .34 |
| | | | C vs. P | 1 | 0.74 | .40 |
| | | Punishment | P vs. B | 1 | 0.06 | .81 |
| Error | | | | 36 | | |
| Task × BAS Fun Seeking | SSRT | Reward | R vs. B | 1 | 0.04 | .84 |
| | | | R vs. P | 1 | 0.02 | .89 |
| | | | R vs. C | 1 | 1.94 | .17 |
| | | Conflict | C vs. B | 1 | 2.44 | .13 |
| | | | C vs. P | 1 | 1.84 | .18 |
| | | Punishment | P vs. B | 1 | 0.18 | .68 |
| Error | | | | 36 | | |
| Task × BAS Reward Responsiveness | SSRT | Reward | R vs. B | 1 | 2.72 | .11 |
| | | | R vs. P | 1 | 3.97 | .05 |
| | | | R vs. C | 1 | 1.91 | .18 |
| | | Conflict | C vs. B | 1 | 0.12 | .73 |
| | | | C vs. P | 1 | 0.38 | .54 |
| | | Punishment | P vs. B | 1 | 0.06 | .81 |
| Error | | | | 36 | | |
| Task × BIS | SSRT | Punishment | P vs. B | 1 | 0.54 | .47 |
| | | | P vs. R | 1 | 2.29 | .14 |
| | | | P vs. C | 1 | 0.24 | .62 |
| | | Conflict | C vs. B | 1 | 0.02 | .88 |
| | | | C vs. R | 1 | 1.05 | .31 |
| | | Reward | R vs. B | 1 | 0.67 | .42 |
| Error | | | | 36 | | |

*Note.* n = 41; SSRT = stop-signal reaction time; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

**p* < .05.

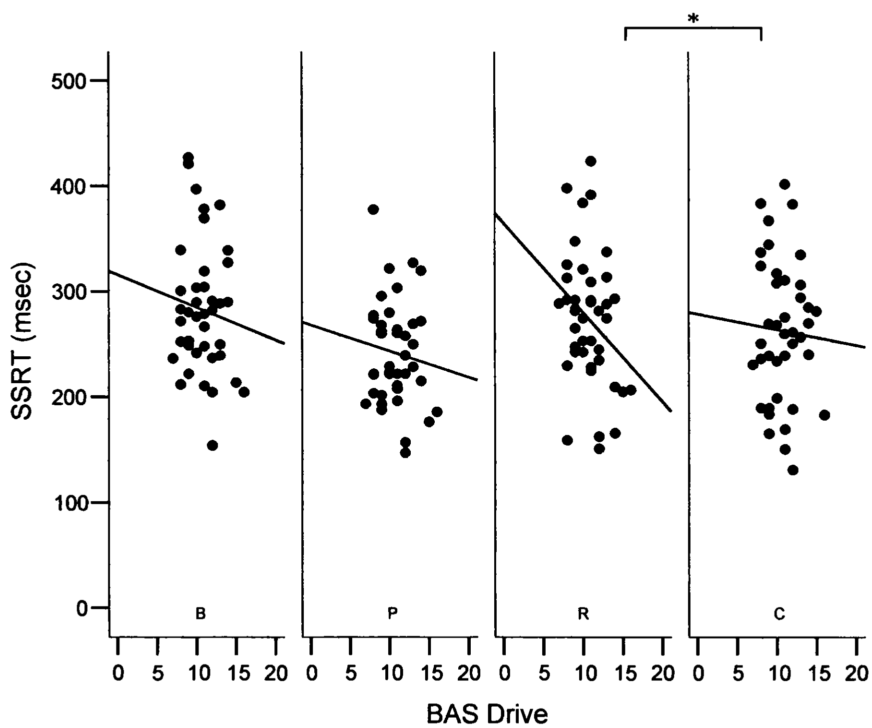


*Figure 4.7.* BAS Drive scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.
$*p < .05$.

The regression lines in panels R and C of Figure 4.7 indicate that, in general, there was a trend toward a higher score on the BAS Drive scale being associated with a faster SSRT (i.e., stronger inhibitory control) on both the Reward and Conflict tasks, and that this trend was stronger on the Reward task than on the Conflict task. However, as expected, there was no significant interaction between Task and the other two BAS measures (Fun Seeking and Reward Responsiveness) when comparing the Reward task with the Conflict task, $p > .05$. This suggests that, consistent with prediction, the response of SSRT to BAS (as measured by these two scales) did not differ between these two tasks. Also consistent with prediction, there was no significant interaction between Task and BIS when comparing the Reward task with the Baseline task, $p > .05$.

There was a near significant interaction between Task and BAS Reward Responsiveness when comparing the Reward task with the Punishment task, $F(1, 36) = 3.97, p = .05$. This suggests that, as expected, the response of SSRT to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.8 displays the correlation between SSRT and BAS Reward Responsiveness on the four stop-signal tasks. The regression lines in panels P and R of Figure 4.8 indicate that, although, in general, contrary to prediction, there was a slight trend toward a higher score on the BAS Reward Responsiveness scale being associated with faster SSRT (i.e., stronger inhibitory control) on the Punishment task, there was a slight trend toward the opposite, predicted, association on the Reward task. However, Table 4.6 shows that, contrary to prediction, there was no significant interaction between Task and the other two BAS measures (Drive and Fun Seeking) when comparing the Reward task with the Punishment task, $p > .05$. Also contrary to prediction, there was no significant interaction between Task and BAS measures (Drive, Fun Seeking, Reward Responsiveness) when comparing the Reward task with the Baseline task, $p > .05$.

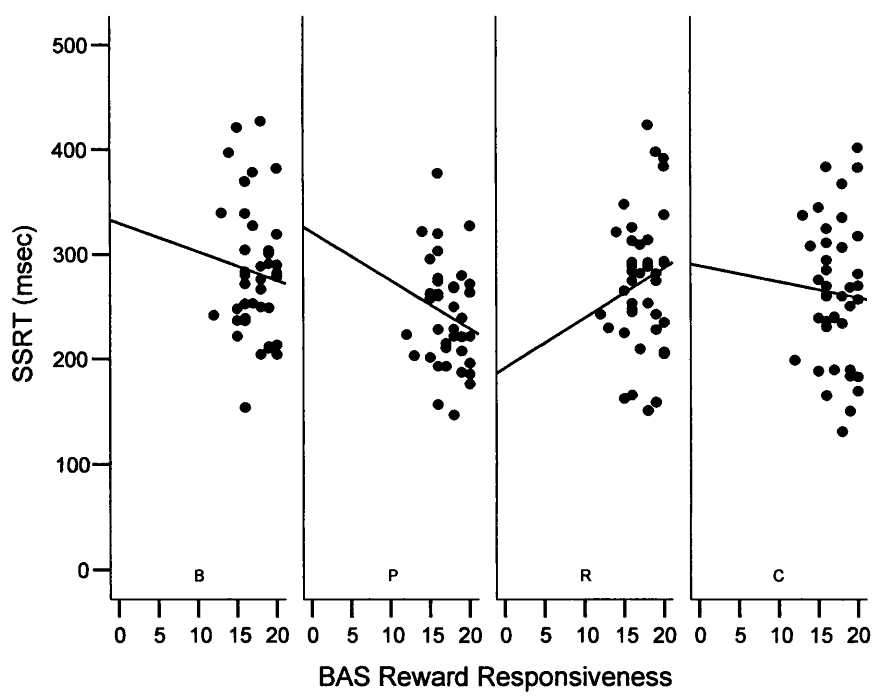


*Figure 4.8.* BAS Reward Responsiveness scores and SSRT (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

Table 4.6 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed no significant interaction between Task and BIS when comparing the Punishment task with the Conflict task, $p > .05$, and no significant interaction between Task and BAS measures (Drive, Fun Seeking, Reward Responsiveness) when comparing the Punishment task with the Baseline task, $p > .05$, consistent with prediction. Contrary to prediction, no other Task × BIS interaction, revealed by simple within-subjects contrasts with the Punishment task selected as the reference category, was significant, $p > .05$. Also contrary to prediction, no Task × BIS or Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

*4.3.1.4.2 Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ)*

*4.3.1.4.2.1 Probability of inhibition on stop-trials*

ANCOVA revealed a significant interaction between Task and Sensitivity to Punishment, $F(3, 114) = 6.13, p < .01$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Sensitivity to Punishment (i.e., BIS) differed according to Task. There was no significant interaction between Task and Sensitivity to Reward, $F(3, 114) = 1.25, p > .05$. The results of the simple within-subjects contrasts for measures of response inhibition (probability of inhibition on stop-trials and SSRT) are summarised in Table 4.7.

Examination of Table 4.7 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Reward task, $F(1, 38) = 17.42, p < .01$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BIS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.9 displays the correlation between probability of inhibition on stop-trials and Sensitivity to Punishment on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.9 indicate that although, contrary to prediction, a higher score on the Sensitivity to Punishment scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .01$, in general, there was a slight trend toward the opposite, predicted, association on the Punishment task.

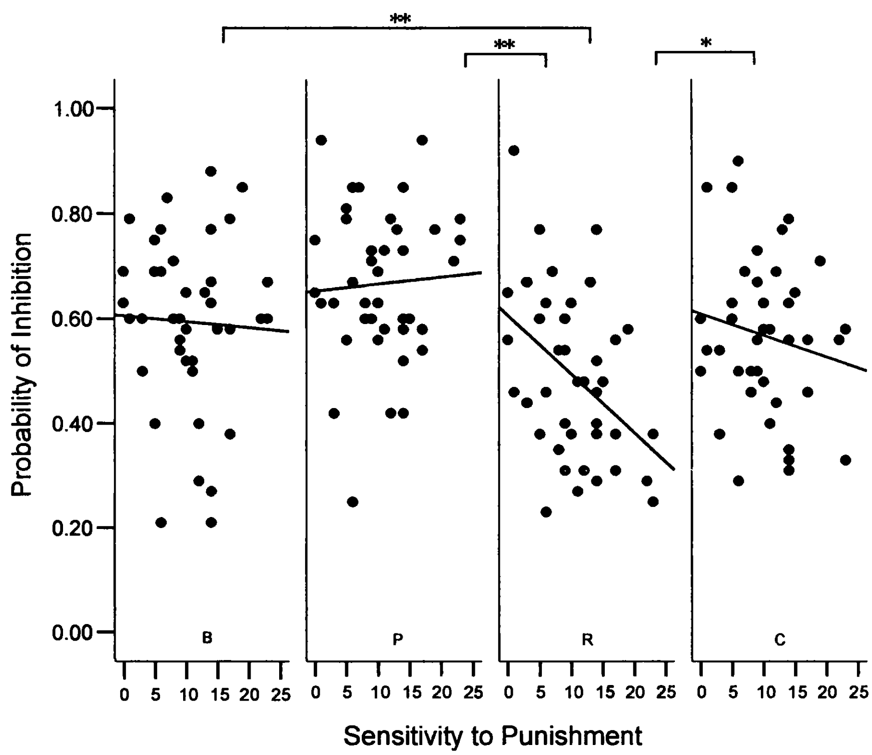


*Figure 4.9.* Sensitivity to Punishment scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$. **$p < .01$.

Table 4.7

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and SPSRQ Measures when Comparing Individual Tasks for Measures of Response Inhibition*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × Sensitivity to Punishment | *P* (In) | Punishment | P vs. B | 1 | 0.46 | .50 |
| | | | P vs. R | 1 | 17.42** | .00 |
| | | | P vs. C | 1 | 3.49 | .07 |
| | | Conflict | C vs. B | 1 | 0.75 | .39 |
| | | | C vs. R | 1 | 6.47* | .02 |
| | | Reward | R vs. B | 1 | 10.74** | .00 |
| | SSRT | Punishment | P vs. B | 1 | 0.04 | .85 |
| | | | P vs. R | 1 | 18.93** | .00 |
| | | | P vs. C | 1 | 5.60* | .02 |
| | | Conflict | C vs. B | 1 | 3.74 | .06 |
| | | | C vs. R | 1 | 2.47 | .12 |
| | | Reward | R vs. B | 1 | 13.77** | .00 |
| Error | | | | 38 | | |
| Task × Sensitivity to Reward | *P* (In) | Reward | R vs. B | 1 | 1.94 | .17 |
| | | | R vs. P | 1 | 0.20 | .66 |
| | | | R vs. C | 1 | 0.12 | .73 |
| | | Conflict | C vs. B | 1 | 0.86 | .36 |
| | | | C vs. P | 1 | 0.67 | .42 |
| | | Punishment | P vs. B | 1 | 3.50 | .07 |
| | SSRT | Reward | R vs. B | 1 | 0.24 | .63 |
| | | | R vs. P | 1 | 5.28* | .03 |
| | | | R vs. C | 1 | 1.83 | .18 |
| | | Conflict | C vs. B | 1 | 0.89 | .35 |
| | | | C vs. P | 1 | 0.40 | .53 |
| | | Punishment | P vs. B | 1 | 3.50 | .07 |
| Error | | | | 38 | | |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

**p* < .05. ***p* < .01.

Contrary to prediction, there was no significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Baseline task, $p > .05$. There was a near significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Conflict task, $F(1, 38) = 3.49$, $p = .07$. This suggests that, contrary to prediction, the response of probability of inhibition on stop-trials to BIS (as measured by this scale) differed according to Task when comparing these two tasks. The regression lines in panels C and P of Figure 4.9 indicate that, in general, there was a slight trend toward a higher score on the Sensitivity to Punishment scale being associated with lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Conflict task whereas there was a slight trend toward the opposite association on the Punishment task.

There was a near significant interaction between Task and Sensitivity to Reward when comparing the Punishment task with the Baseline task, $F(1, 38) = 3.50$, $p = .07$. This suggests that, contrary to prediction, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.10 displays the correlation between probability of inhibition on stop-trials and Sensitivity to Reward on the four stop-signal tasks. The regression lines in panels B and P of Figure 4.10 indicate that, in general, there was no apparent trend toward an association between Sensitivity to Reward score and probability of inhibition on stop-trials on the Baseline task whereas there was a slight trend toward a higher score on the Sensitivity to Reward scale being associated with higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Punishment task.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed, contrary to prediction, a significant interaction between Task and Sensitivity to Punishment when comparing the Reward task with the Baseline task, $F(1, 38) = 10.74$, $p < .01$. The regression lines in panels R and B of Figure 4.9 indicate that a higher score on the Sensitivity to Punishment scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .01$, whereas, in general, there was no apparent trend toward an association between

Sensitivity to Punishment score and probability of inhibition on stop-trials on the Baseline task. As expected, there was no significant interaction between Task and Sensitivity to Reward when comparing the Reward task with the Conflict task, $p > .05$. This suggests that, consistent with prediction, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) did not differ between these two tasks. Table 4.7 shows that, contrary to prediction, no other Task × Sensitivity to Reward interaction, revealed by simple within-subjects contrasts with the Reward task selected as the reference category, was significant, $p > .05$.

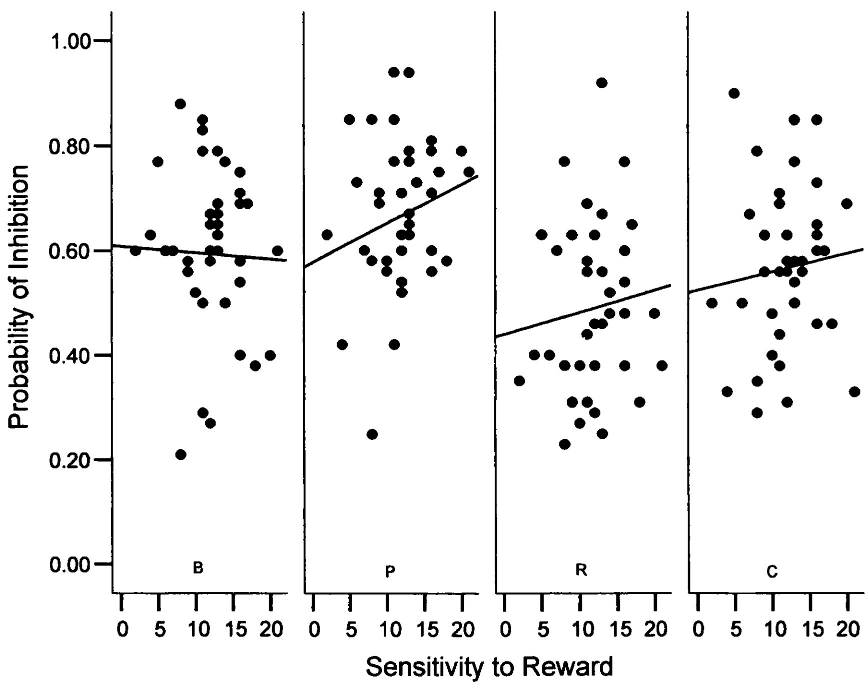


*Figure 4.10.* Sensitivity to Reward scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

Simple within-subjects contrasts with the Conflict stop-signal task selected as the reference category revealed, as expected, a significant interaction between Task and Sensitivity to Punishment when comparing the Conflict task with the Reward task, $F(1, 38) = 6.47, p < .05$. The regression lines in panels R and C of Figure 4.9 indicate that, contrary to prediction, a higher score on the Sensitivity to Punishment scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .01$, whereas, in general, there was only a slight trend toward this same association on the Conflict task. Table 4.7 shows that, contrary to prediction, no other Task × Sensitivity to Punishment or Task × Sensitivity to Reward interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

*4.3.1.4.2.2 Stop-signal reaction time (SSRT)*

ANCOVA revealed a significant interaction between Task and Sensitivity to Punishment, $F(3, 114) = 7.25$, $p < .01$. This suggests that, as expected, the response of SSRT to Sensitivity to Punishment (i.e., BIS) differed according to Task. There was no significant interaction between Task and Sensitivity to Reward, $F(3, 114) = 1.85$, $p > .05$. Examination of Table 4.7 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Reward task, $F(1, 38) = 18.93$, $p < .01$. This suggests that, as expected, the response of SSRT to BIS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.11 displays the correlation between SSRT and Sensitivity to Punishment on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.11 indicate that although, contrary to prediction, a higher score on the Sensitivity to Punishment scale was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, in general, there was a slight trend toward the opposite, predicted, association on the Punishment task.

There was a significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Conflict task, $F(1, 38) = 5.60$, $p < .05$, contrary to prediction. The regression lines in panels C and P of Figure 4.11 indicate that, in general, there was a slight trend toward a higher score on the Sensitivity to Punishment scale being associated with a slower SSRT (i.e., weaker inhibitory control) on the Conflict task whereas there was a slight trend toward the opposite association on the Punishment task. There was a near significant interaction between Task and Sensitivity to Reward when comparing the Punishment task with the Baseline task, $F(1, 38) = 3.50$, $p = .07$. This suggests that, contrary to prediction, the response of SSRT to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.12 displays the correlation between SSRT and Sensitivity to Reward on the four stop-signal tasks. The regression lines in panels B and P of Figure 4.12 indicate that, in general, there was a slight trend toward a higher score on the Sensitivity to Reward scale being associated with a slower SSRT (i.e., weaker inhibitory control) on the Baseline task whereas there was a slight trend toward the opposite association on the Punishment task. Contrary to prediction, there was no significant interaction between Task and Sensitivity to Punishment when comparing the Punishment task with the Baseline task, $p > .05$.

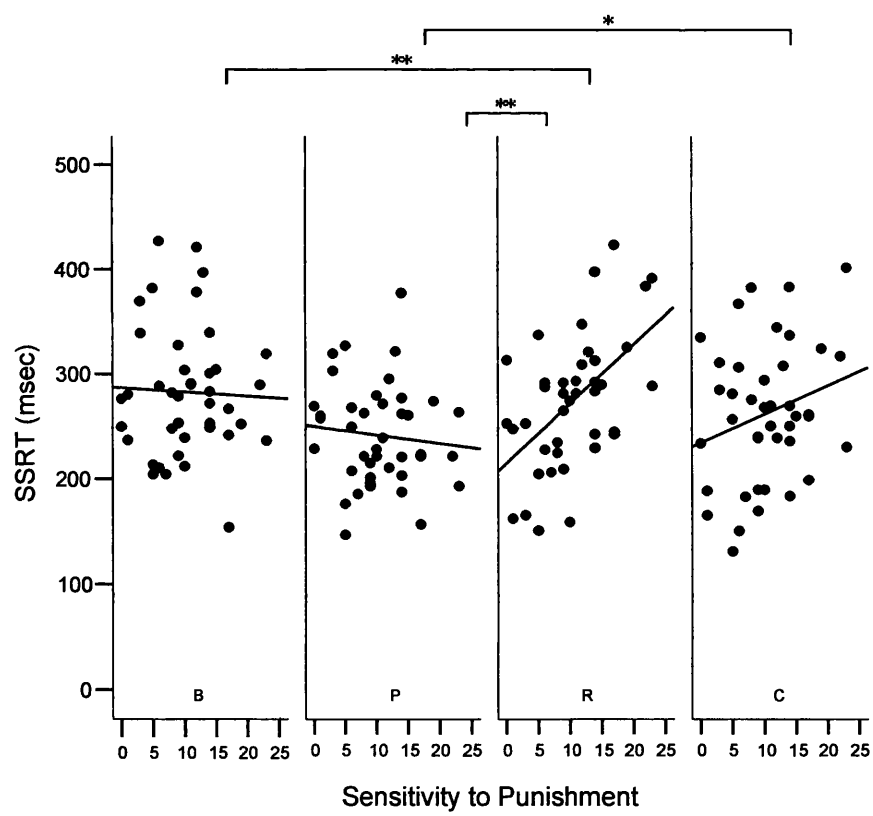


*Figure 4.11.* Sensitivity to Punishment scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks. *$p < .05$. **$p < .01$.

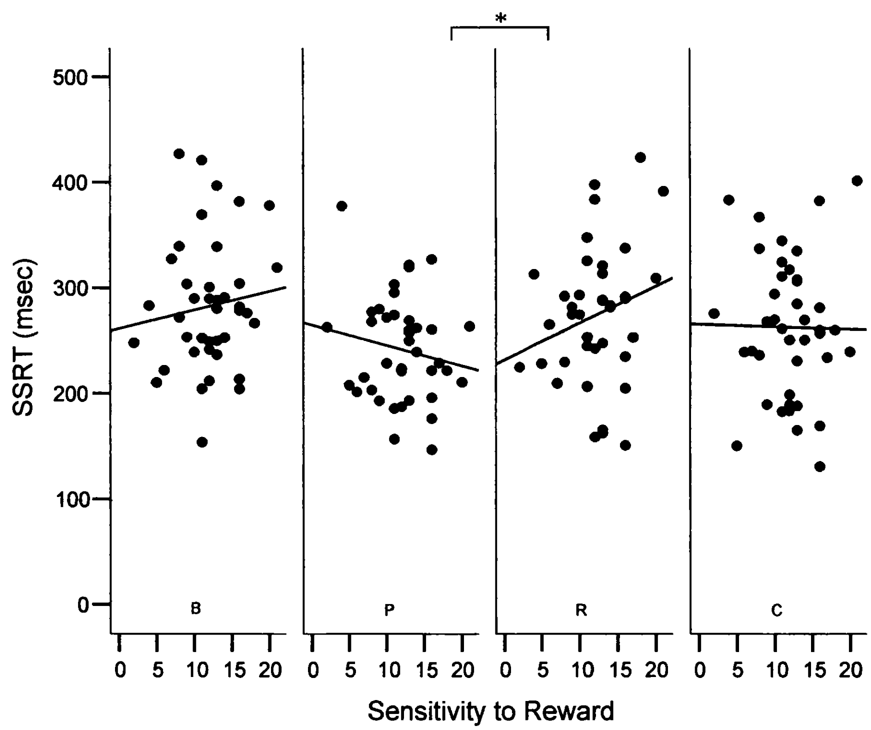


*Figure 4.12.* Sensitivity to Reward scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks. *$p < .05$.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and Sensitivity to Punishment when comparing the Baseline task with the Reward task, $F(1, 38) = 13.77, p < .01$, contrary to prediction. The regression lines in panels R and B of Figure 4.11 indicate that, a higher score on the Sensitivity to Punishment scale was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, whereas, in general, there was no apparent trend toward an association between Sensitivity to Punishment score and SSRT on the Baseline task.

As expected, there was a significant interaction between Task and Sensitivity to Reward when comparing the Reward task with the Punishment task, $F(1, 38) = 5.28, p < .05$. The regression lines in panels P and R of Figure 4.12 indicate that although, in general, contrary to prediction, there was a slight trend toward a higher score on the Sensitivity to Reward scale being associated with a faster

SSRT (i.e., stronger inhibitory control) on the Punishment task, there was a slight trend toward the opposite, predicted, association on the Reward task. Table 4.7 shows that, as expected, there was no significant interaction between Task and Sensitivity to Reward when comparing the Reward task with the Conflict task, $p > .05$. This suggests that, consistent with prediction, the response of SSRT to BAS (as measured by this scale) did not differ between these two tasks. Contrary to prediction, there was no significant interaction between Task and Sensitivity to Reward when comparing the Reward task with the Baseline task, $p > .05$.

Simple within-subjects contrasts with the Conflict task selected as the reference category revealed a near significant interaction between Task and Sensitivity to Punishment when comparing the Conflict task with the Baseline task, $F(1, 38) = 3.74$, $p = .06$. This suggests that, as expected, the response of SSRT to BIS (as measured by this scale) differed according to Task when comparing these two tasks. The regression lines in panels C and B of Figure 4.11 indicate that, in general, contrary to prediction, there was a slight trend toward a higher score on the Sensitivity to Punishment scale being associated with a slower SSRT (i.e., weaker inhibitory control) on the Conflict task whereas there was no apparent trend toward an association between Sensitivity to Punishment score and SSRT on the Baseline task. Table 4.7 shows that, contrary to prediction, no other Task × Sensitivity to Punishment or Task × Sensitivity to Reward interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

*4.3.1.4.3 Revised Eysenck Personality Questionnaire short scale (EPQ-RS)*

*4.3.1.4.3.1 Probability of inhibition on stop-trials*

ANCOVA revealed a significant interaction between Task and Neuroticism, $F(3, 108) = 3.18$, $p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Neuroticism differed according to Task. There was a near significant interaction between Task and Extraversion, $F(3, 108) = 2.20$, $p = .09$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Extraversion differed according to Task. There was no significant interaction between Task and Psychoticism, $F(3, 108) = 0.17, p > .05$, or between Task and Lie, $F(3, 108) = 0.74, p > .05$. The results of the simple within-subjects contrasts for measures of response inhibition (probability of inhibition on stop-trials and SSRT) are summarised in Table 4.8. Examination of Table 4.8 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Neuroticism when comparing the Punishment task with the Baseline task, $F(1, 36) = 5.06, p < .05$, and when comparing the Punishment task with the Reward task, $F(1, 36) = 6.76, p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Neuroticism differed according to Task when comparing the Punishment task with the Baseline task and when comparing the Punishment task with the Reward task. Figure 4.13 displays the correlation between probability of inhibition on stop-trials and Neuroticism on the four stop-signal tasks.

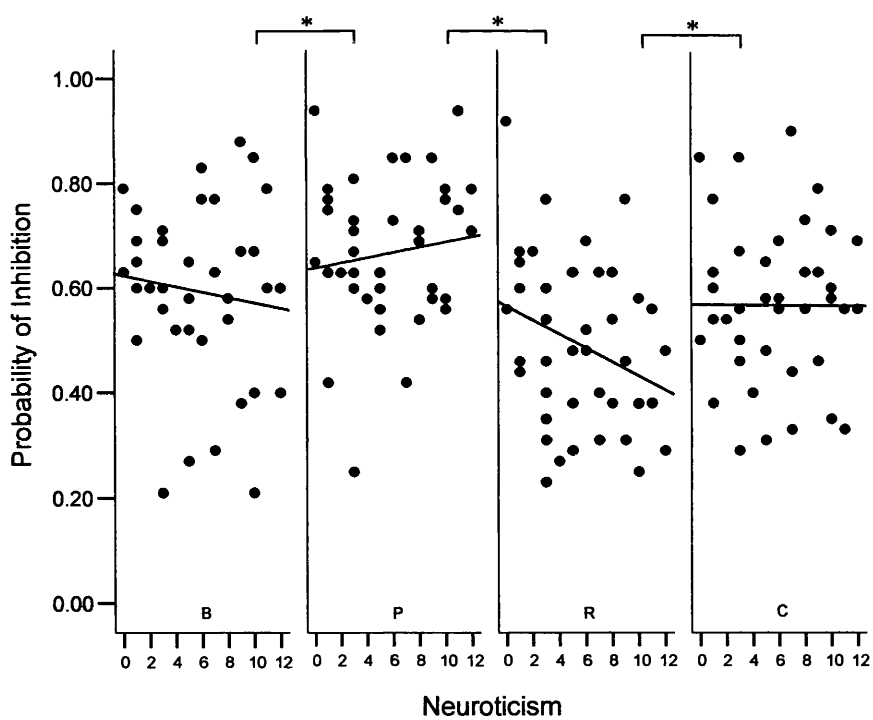


*Figure 4.13.* Neuroticism scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$.

Table 4.8

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and Extraversion/Neuroticism when Comparing Individual Tasks for Measures of Response Inhibition*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × Extraversion | *P* (In) | Reward | R vs. B | 1 | 5.46* | .03 |
| | | | R vs. P | 1 | 1.06 | .31 |
| | | | R vs. C | 1 | 0.51 | .48 |
| | | Conflict | C vs. B | 1 | 2.52 | .12 |
| | | | C vs. P | 1 | 0.18 | .67 |
| | | Punishment | P vs. B | 1 | 2.27 | .14 |
| | SSRT | Reward | R vs. B | 1 | 4.15* | .05 |
| | | | R vs. P | 1 | 0.89 | .35 |
| | | | R vs. C | 1 | 0.35 | .56 |
| | | Conflict | C vs. B | 1 | 1.87 | .18 |
| | | | C vs. P | 1 | 0.12 | .73 |
| | | Punishment | P vs. B | 1 | 1.93 | .17 |
| Error | | | | 36 | | |
| Task × Neuroticism | *P* (In) | Punishment | P vs. B | 1 | 5.06* | .03 |
| | | | P vs. R | 1 | 6.76* | .01 |
| | | | P vs. C | 1 | 0.25 | .62 |
| | | Conflict | C vs. B | 1 | 2.14 | .15 |
| | | | C vs. R | 1 | 5.85* | .02 |
| | | Reward | R vs. B | 1 | 0.15 | .70 |
| | SSRT | Punishment | P vs. B | 1 | 1.76 | .19 |
| | | | P vs. R | 1 | 7.82** | .01 |
| | | | P vs. C | 1 | 1.42 | .24 |
| | | Conflict | C vs. B | 1 | 0.00 | .99 |
| | | | C vs. R | 1 | 2.56 | .12 |
| | | Reward | R vs. B | 1 | 2.63 | .11 |
| Error | | | | 36 | | |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

*$p < .05$. **$p < .01$.

The regression lines in panels R, B and P of Figure 4.13 indicate that although, contrary to prediction, a higher score on the Neuroticism scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p = .06$, and, in general, there was a slight trend toward this same association on the Baseline task, there was a slight trend toward the opposite, predicted, association on the Punishment task. No other Task × Neuroticism or Task × Extraversion interaction, revealed by simple within-subjects contrasts with the Punishment task selected as the reference category, was significant, $p > .05$.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed, as expected, a significant interaction between Task and Extraversion when comparing the Reward task with the Baseline task, $F(1, 36) = 5.46$, $p < .05$. Figure 4.14 displays the correlation between probability of inhibition on stop-trials and Extraversion on the four stop-signal tasks. The regression lines in panels R and B of Figure 4.14 indicate that, contrary to prediction, a higher score on the Extraversion scale was related to a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Reward task, $p = .06$, whereas, in general, there was no apparent trend toward an association between Extraversion score and probability of inhibition on stop-trials on the Baseline task. Table 4.8 shows that, contrary to prediction, no other Task × Extraversion interaction, revealed by simple within-subjects contrasts with the Reward task selected as the reference category, was significant, $p > .05$. There was no significant interaction between Task and Neuroticism when comparing the Reward task with the Baseline task, $p > .05$.

Simple within-subjects contrasts with the Conflict task selected as the reference category revealed, as expected, a significant interaction between Task and Neuroticism when comparing the Conflict task with the Reward task, $F(1, 36) = 5.85$, $p < .05$. The regression lines in panels R and C of Figure 4.13 indicate that, contrary to prediction, a higher score on the Neuroticism scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p = .06$, whereas, in general, there was no apparent trend toward an association between Neuroticism score and probability of inhibition on stop-trials on the Conflict task. Table 4.8 shows that, contrary to prediction, no other Task × Neuroticism or Task × Extraversion interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

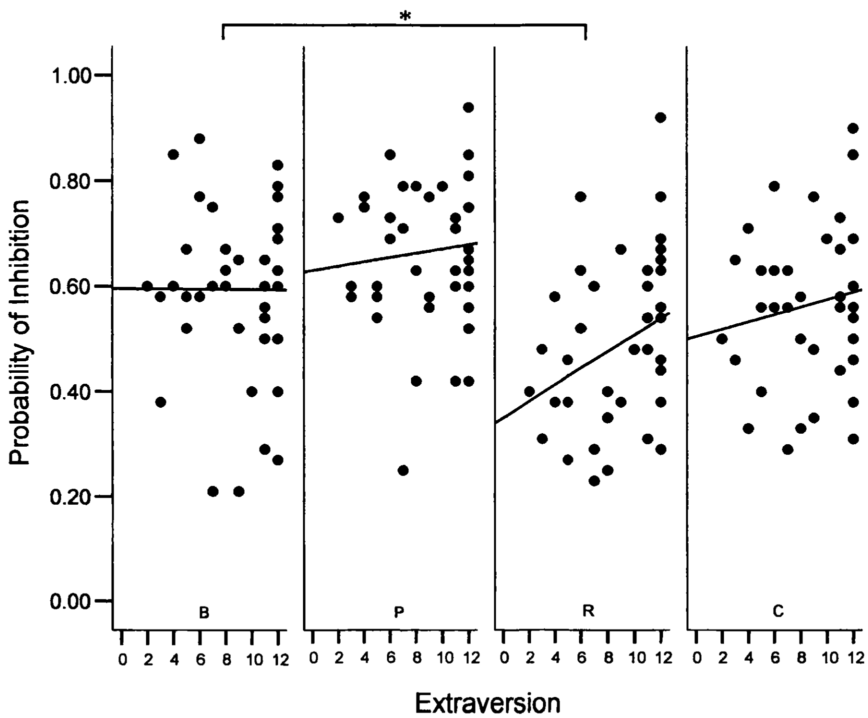


*Figure 4.14.* Extraversion scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$.

#### *4.3.1.4.3.2 Stop-signal reaction time (SSRT)*

ANCOVA revealed a near significant interaction between Task and Neuroticism, $F(3, 108) = 2.69$, $p = .05$. This suggests that, as expected, the response of SSRT to Neuroticism differed according to Task. There was no significant interaction between Task and Extraversion, $F(3, 108) = 1.58, p > .05$, between Task and Psychoticism, $F(3, 108) = 0.23, p > .05$, or between Task and Lie, $F(3, 108) = 1.78, p > .05$.

Examination of Table 4.8 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Neuroticism when comparing the Punishment task with the Reward task, $F(1, 36) = 7.82, p < .01$. This suggests that, as expected, the response of SSRT to Neuroticism differed according to Task when comparing these two tasks. Figure 4.15 displays the correlation between SSRT and Neuroticism on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.15 indicate that although, contrary to prediction, a higher score on the Neuroticism scale was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, in general, there was a slight trend toward the opposite, predicted, association on the Punishment task. Contrary to prediction, no other Task × Neuroticism or Task × Extraversion interaction, revealed by simple within-subjects contrasts with the Punishment task selected as the reference category, was significant, $p > .05$.

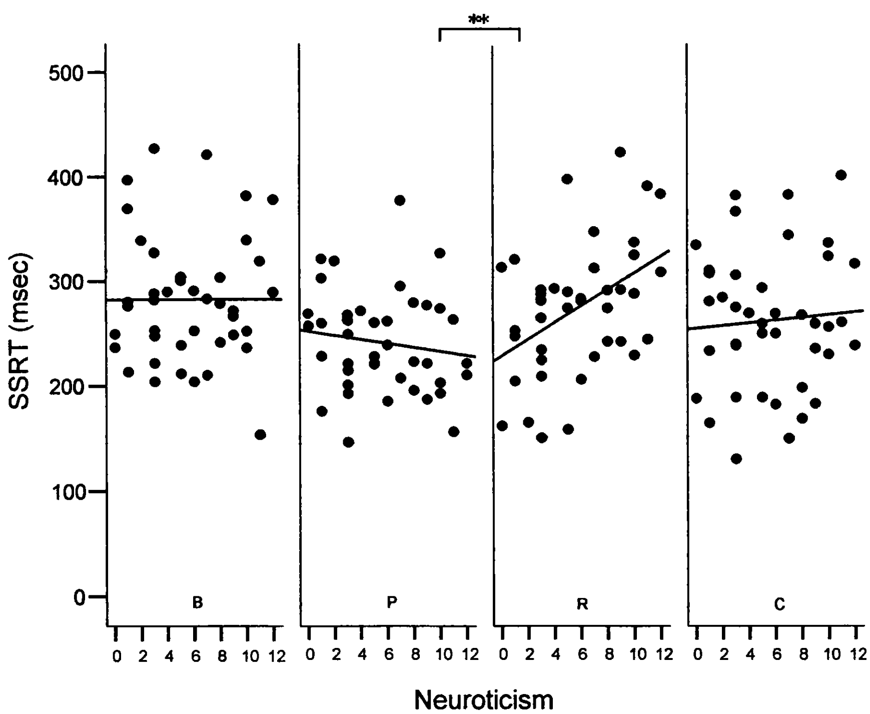


*Figure 4.15.* Neuroticism scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

$^{**}p < .01$.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed, as expected, a significant interaction between Task and Extraversion when comparing the Reward task with the Baseline task, $F(1, 36) = 4.15, p < .05$. Figure 4.16 displays the correlation between SSRT and Extraversion on the four stop-signal tasks. The regression lines in panels R and B of Figure 4.16 indicate that, contrary to prediction, a higher score on the Extraversion scale was related to a faster SSRT (i.e., stronger inhibitory control) on the Reward task, $p < .05$, whereas, in general, there was no apparent trend toward an association between Extraversion score and SSRT on the Baseline task. Also contrary to prediction, Table 4.8 shows that no other Task × Neuroticism or Task × Extraversion interaction, revealed by simple within-subjects contrasts with the Reward or the Conflict task selected as the reference category, was significant, $p > .05$.

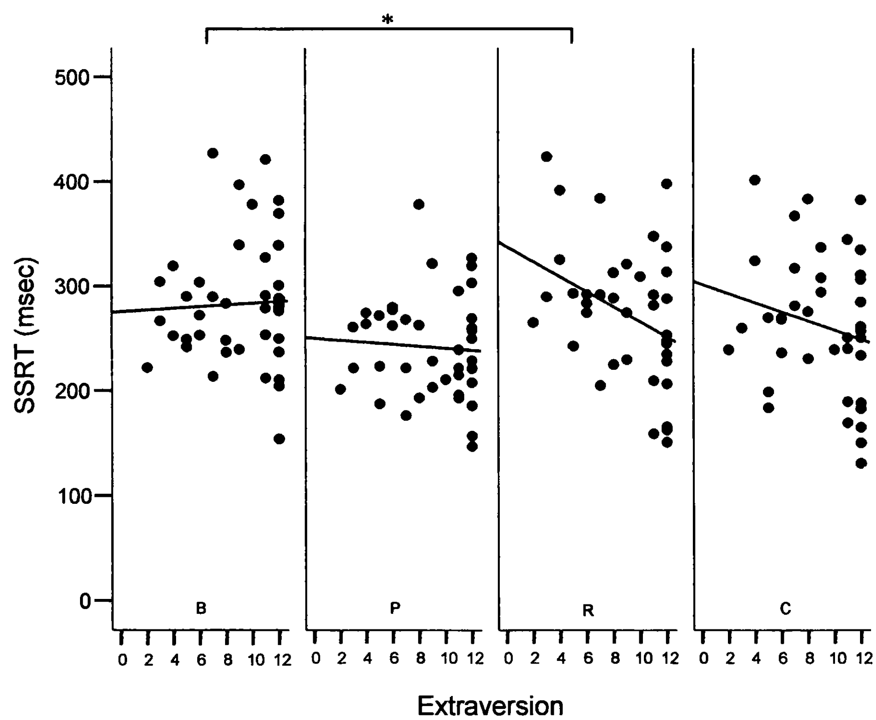


*Figure 4.16.* Extraversion scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$.

*4.3.1.4.4 Spielberger State-Trait Anxiety Inventory (STAI)*

*4.3.1.4.4.1 Probability of inhibition on stop-trials*

ANCOVA revealed a significant interaction between Task and STAI, $F(3, 117) = 6.04, p < .01$. This suggests that, as expected, the response of probability of inhibition on stop-trials to STAI (i.e., BIS) differed according to Task. The results of the simple within-subjects contrasts for measures of response inhibition (probability of inhibition on stop-trials and SSRT) are summarised in Table 4.9.

Table 4.9

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and STAI when Comparing Individual Tasks for Measures of Response Inhibition*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × STAI | *P* (In) | Punishment | P vs. B | 1 | 1.48 | .23 |
| | | | P vs. R | 1 | 19.74** | .00 |
| | | | P vs. C | 1 | 4.29* | .05 |
| | | Conflict | C vs. B | 1 | 0.29 | .59 |
| | | | C vs. R | 1 | 6.58* | .01 |
| | | Reward | R vs. B | 1 | 7.76** | .01 |
| | SSRT | Punishment | P vs. B | 1 | 0.00 | .97 |
| | | | P vs. R | 1 | 20.10** | .00 |
| | | | P vs. C | 1 | 3.82 | .06 |
| | | Conflict | C vs. B | 1 | 3.17 | .08 |
| | | | C vs. R | 1 | 4.69* | .04 |
| | | Reward | R vs. B | 1 | 19.45** | .00 |
| Error | | | | 39 | | |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

**p* < .05. ***p* < .01.

Examination of Table 4.9 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and STAI when comparing the Punishment task with the Reward task, $F(1, 39) = 19.74, p < .01$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BIS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.17 displays the correlation between probability of inhibition on stop-trials and STAI on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.17 indicate that although, contrary to prediction, a higher score on the STAI was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .05$, in general, there was a slight trend toward the opposite, predicted, association on the Punishment task.

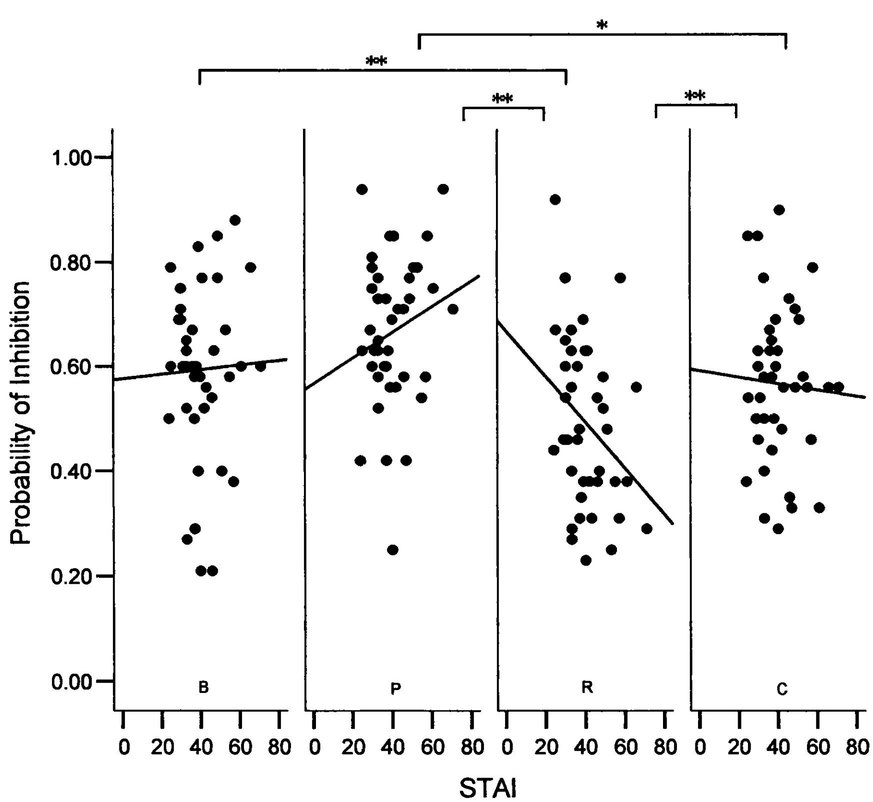


*Figure 4.17.* Spielberger State-Trait Anxiety Inventory (STAI) scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$. **$p < .01$.

There was a significant interaction between Task and STAI when comparing the Punishment task with the Conflict task, $F(1, 39) = 4.29, p < .05$, contrary to prediction. The regression lines in panels C and P of Figure 4.17 indicate that, in general, there was a slight trend toward a higher score on the STAI being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Conflict task whereas there was a slight trend toward the opposite association on the Punishment task. Also contrary to prediction, there was no significant interaction between Task and STAI when comparing the Punishment task with the Baseline task, $p > .05$.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and STAI when comparing the Reward task with the Baseline task, $F(1, 39) = 7.76, p < .01$, contrary to prediction. The regression lines in panels R and B of Figure 4.17 indicate that a higher score on the STAI was related to a lower probability of inhibition on stop-trials, $p < .05$, (i.e., weaker inhibitory control) on the Reward task whereas, in general, there was a slight trend toward the opposite association on the Baseline task. Simple within-subjects contrasts with the Conflict task selected as the reference category revealed, as expected, a significant interaction between Task and STAI when comparing the Conflict task with the Reward task, $F(1, 39) = 6.58, p < .01$. The regression lines in panels R and C of Figure 4.17 indicate that, contrary to prediction, a higher score on the STAI was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .05$, whereas, in general, there was only a slight trend toward this same association on the Conflict task. Table 4.9 shows that, contrary to prediction, there was no significant interaction between Task and STAI when comparing the Conflict task with the Baseline task, $p > .05$.

*4.3.1.4.4.2 Stop-signal reaction time (SSRT)*

ANCOVA revealed a significant interaction between Task and STAI, $F(3, 117) = 8.37, p < .01$. This suggests that, as expected, the response of SSRT to STAI (i.e., BIS) differed according to Task. Examination of Table 4.9 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and STAI when comparing the Punishment task with the Reward task, $F(1, 39) = 20.10$, $p < .01$. This suggests that, as expected, the response of SSRT to BIS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 4.18 displays the correlation between SSRT and STAI on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.18 indicate that although, contrary to prediction, a higher score on the STAI was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, in general, there was a slight trend toward the opposite, predicted, association on the Punishment task.

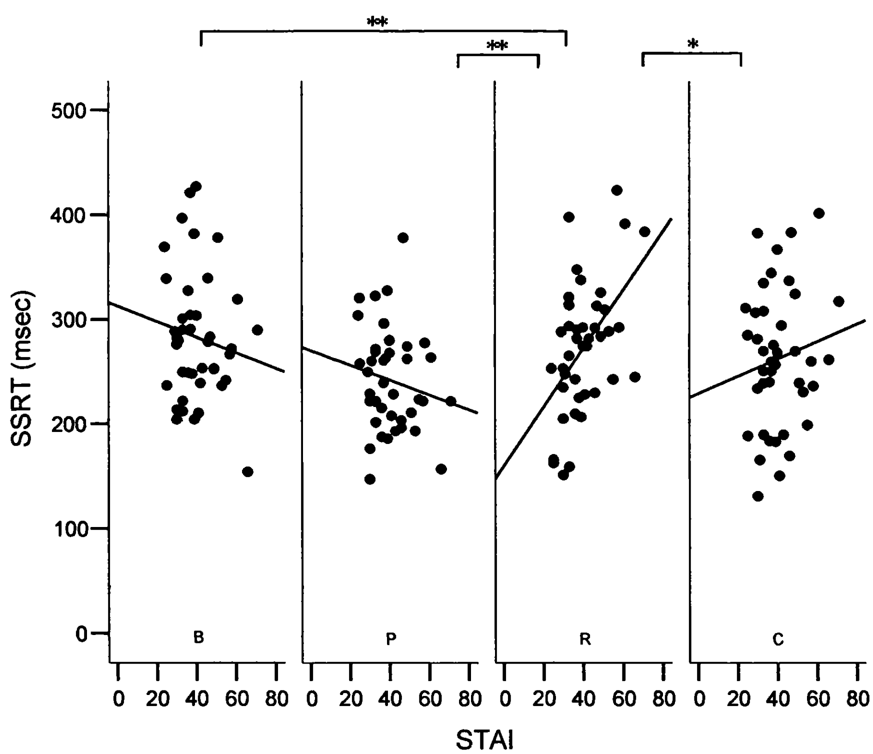


*Figure 4.18.* Spielberger State-Trait Anxiety Inventory (STAI) scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks.

*$p < .05$. **$p < .01$.

There was a near significant interaction between Task and STAI when comparing the Punishment task with the Conflict task, $F(1, 39) = 3.82$, $p = .06$. This suggests that, contrary to prediction, the response of SSRT to BIS (as measured by this scale) differed according to Task when comparing these two tasks. The regression lines in panels C and P of Figure 4.18 indicate that, in general, there was a slight trend toward a higher score on the STAI being associated with a slower SSRT (i.e., weaker inhibitory control) on the Conflict task whereas there was a slight trend toward the opposite association on the Punishment task. Contrary to prediction, there was no significant interaction between Task and STAI when comparing the Punishment task with the Baseline task, $p > .05$. Simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and STAI when comparing the Reward task with the Baseline task, $F(1, 39) = 19.45$, $p < .01$, contrary to prediction. The regression lines in panels R and B of Figure 4.18 indicate that a higher score on the STAI was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, whereas, in general, there was a slight trend toward the opposite, predicted, association on the Baseline task.

Simple within-subjects contrasts with the Conflict task selected as the reference category revealed, as expected, a significant interaction between Task and STAI when comparing the Conflict task with the Reward task, $F(1, 39) = 4.69$, $p < .05$. The regression lines in panels R and C of Figure 4.18 indicate that, contrary to prediction, a higher score on the STAI was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .01$, whereas, in general, there was only a slight trend toward this same association on the Conflict task. There was a near significant interaction between Task and STAI when comparing the Conflict task with the Baseline task, $F(1, 40) = 3.17$, $p = .08$. This suggests that, as expected, the response of SSRT to BIS (as measured by this scale) differed according to Task when comparing these two tasks. The regression lines in panels C and B of Figure 4.18 indicate that although, in general, contrary to prediction, there was a slight trend toward a higher score on the STAI being associated with a slower SSRT (i.e., weaker inhibitory control) on the Conflict task, there was a slight trend toward the opposite, predicted, association on the Baseline task.

#### 4.3.1.4.5 Fear Survey Schedule (FSS)

##### 4.3.1.4.5.1 Probability of inhibition on stop-trials

ANCOVA revealed a near significant interaction between Task and Fear, $F(3, 117) = 2.26$, $p = .09$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Fear differed according to Task. The results of the simple within-subjects contrasts for measures of response inhibition (probability of inhibition on stop-trials and SSRT) are summarised in Table 4.10.

Table 4.10

*Summary of Simple Within-subjects Contrasts Showing Interaction Effects between Task and Fear when Comparing Individual Tasks for Measures of Response Inhibition*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task × Fear | *P* (In) | Punishment | P vs. B | 1 | 0.01 | .92 |
| | | | P vs. R | 1 | 4.61* | .04 |
| | | | P vs. C | 1 | 2.29 | .14 |
| | | Conflict | C vs. B | 1 | 1.20 | .28 |
| | | | C vs. R | 1 | 0.96 | .33 |
| | | Reward | R vs. B | 1 | 4.14* | .05 |
| | SSRT | Punishment | P vs. B | 1 | 0.02 | .90 |
| | | | P vs. R | 1 | 5.03* | .03 |
| | | | P vs. C | 1 | 3.05 | .09 |
| | | Conflict | C vs. B | 1 | 2.11 | .16 |
| | | | C vs. R | 1 | 0.46 | .50 |
| | | Reward | R vs. B | 1 | 4.34* | .04 |
| Error | | | | 39 | | |

*Note.* n = 41; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; R = Reward; P = Punishment; C = Conflict; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task.

*$p < .05$.

Examination of Table 4.10 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Fear when comparing the Punishment task with the Reward task, $F(1, 39) = 4.61, p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Fear differed according to Task when comparing these two tasks. Figure 4.19 displays the correlation between probability of inhibition on stop-trials and Fear on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.19 indicate that although, in general, contrary to prediction, there was a moderate trend toward a higher Fear score being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, there was a slight trend toward the opposite, predicted, association on the Punishment task. No other Task × Fear interaction, revealed by simple within-subjects contrasts with the Punishment task selected as the reference category, was significant, $p > .05$, contrary to prediction.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and Fear when comparing the Reward task with the Baseline task, $F(1, 39) = 4.14, p < .05$. The regression lines in panels R and B of Figure 4.19 indicate that, in general, there was a slight trend toward a higher Fear score being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task whereas there was no apparent trend toward an association between Fear score and probability of inhibition on stop-trials on the Baseline task. Table 4.10 shows that, contrary to prediction, no Task × Fear interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

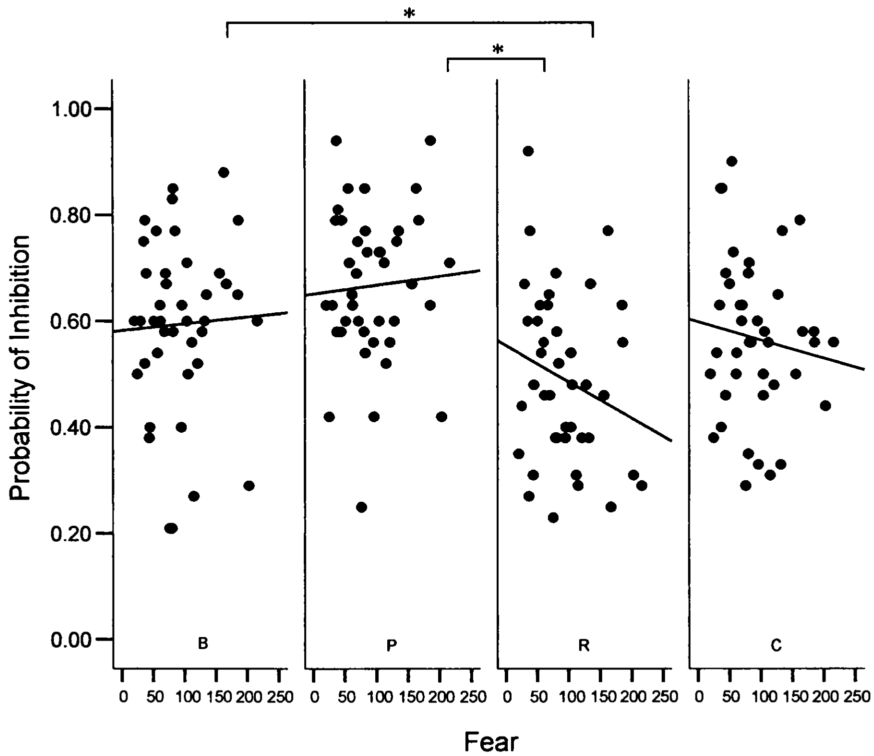


*Figure 4.19.* Fear Survey Schedule (FSS) Fear scores and probability of inhibition on stop-trials (with regression line) Baseline (panel B), Punishment (panel P), Reward (panel R) and Conflict (panel C), stop-signal tasks.

*$p < .05$.

*4.3.1.4.5.2 Stop-signal reaction time (SSRT)*

ANCOVA revealed a near significant interaction between Task and Fear, $F(3, 117) = 2.62, p = .05$. This suggests that, as expected, the response of SSRT to Fear differed according to Task. Examination of Table 4.10 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Fear when comparing the Punishment task with the Reward task, $F(1, 39) = 5.03, p < .05$. This suggests that, as expected, the response of SSRT to Fear differed according to Task when comparing these two tasks. Figure 4.20 displays the correlation between SSRT and Fear on the four stop-signal tasks. The regression lines in panels R and P of Figure 4.20 indicate that, contrary to prediction, a higher Fear score was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .05$, whereas, in general, there was no apparent trend toward an association between Fear score and SSRT on the Punishment task.

There was a near significant interaction between Task and Fear when comparing the Punishment task with the Conflict task, $F(1, 39) = 3.05$, $p = .09$. This suggests that the response of SSRT to Fear differed according to Task when comparing these two tasks. The regression lines in panels C and P of Figure 4.20 indicate that, in general, there was a slight trend toward a higher Fear score being associated with a slower SSRT (i.e., weaker inhibitory control) on the Conflict task whereas there was no apparent trend toward an association between Fear score and SSRT on the Punishment task. There was no significant interaction between Task and Fear when comparing the Punishment task with the Baseline task, $p > .05$, contrary to prediction.

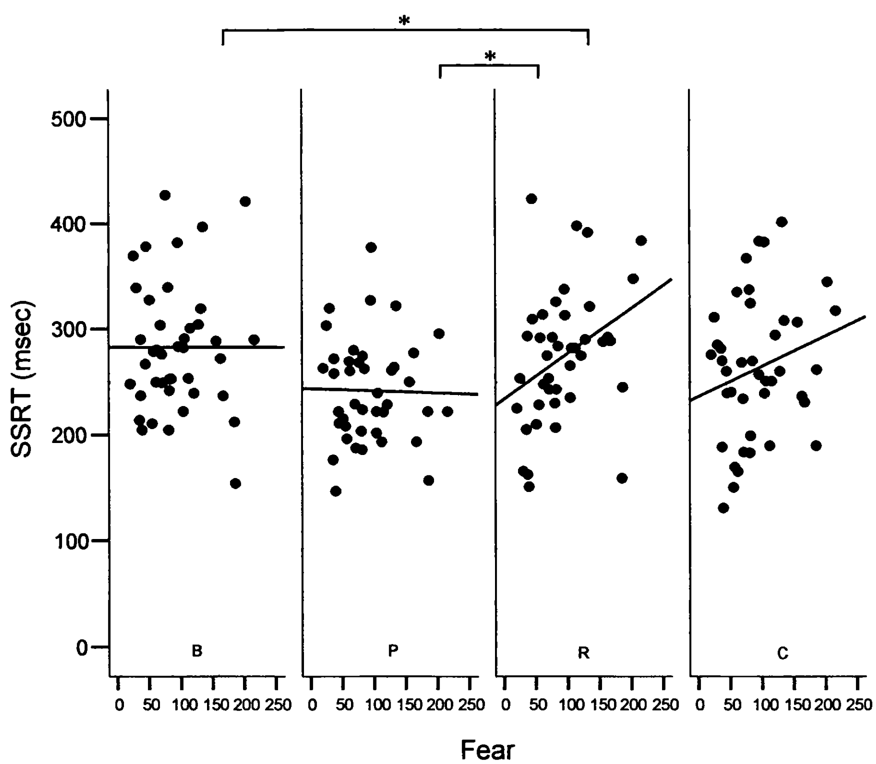


*Figure 4.20.* Fear Survey Schedule (FSS) Fear scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C), stop-signal tasks. *$p < .05$.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and Fear when comparing the Reward task with the Baseline task, $F(1, 39) = 4.34$, $p < .05$. The regression lines in panels R and B of Figure 4.20 indicate that a higher Fear score was related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task, $p < .05$, whereas, in general, there was no apparent trend toward an association between Fear score and SSRT on the Baseline task. Table 4.10 shows that, contrary to prediction, no Task × Fear interaction, revealed by simple within-subjects contrasts with the Conflict task selected as the reference category, was significant, $p > .05$.

#### *4.3.1.5 Personality and affect following stop-signal task performance*

One case with extremely high z scores (beyond the $p = .001$ criterion of 3.29, two-tailed) on negative affect following performance of the Baseline, Punishment, Reward, and Conflict tasks, was found to be a univariate outlier. The outlier was deleted, leaving 40 cases for analysis. Table 4.11 shows correlations between the two dependent measures of affect following the four tasks and personality measures, age and sex. Due to the presence of significant correlations between the EPQ-RS Lie scale and positive affect following the Conflict task, $r(39) = .33$, $p < .05$, and between sex and positive affect following the Baseline task, $r(39) = -.40$, $p < .05$, Table 4.11 also shows partial correlations, controlling for Lie score and sex, between the two dependent measures of affect following the four tasks and personality measures and age.

Partial correlations shown in Table 4.11 revealed a near significant correlation between positive affect following the Reward task and Bas Drive, $r(36) = -.28$, $p = .09$. The negative sign of this correlation reflects a higher score on the Bas Drive scale being related to a lower positive affect following performance of the Reward task. The association between positive affect following this same task and Extraversion, although not significant, was in this same direction, $r(36) = -.24$, $p > .05$. Potentially, these results suggest that higher BAS activity (at least, as measured by the BAS Drive scale) and higher Extraversion were actually associated with finding the Reward task less rewarding than lower BAS activity and lower Extraversion were. These results could help to explain the unexpected results obtained concerning associations between response inhibition and BAS measures and Extraversion on and across tasks (see sections 4.3.1.3.1, 4.3.1.4.1.2, and 4.3.1.4.3). The near significant partial correlation revealed between positive affect following the Conflict task and BAS Reward Responsiveness, $r(36) = .28$, $p = .09$, however, reflects the opposite association (i.e., higher BAS Reward Responsiveness related to higher positive affect following performance of the Conflict task). The association between this BAS measure and positive affect following the Reward task, although not significant, was in this same direction, $r(36) = .17$, $p > .05$. Results obtained concerning associations between this particular BAS measure and inhibitory control on the Reward task were more in line with prediction (see figure 4.8), perhaps explained by higher BAS Reward Responsiveness activity being associated with finding tasks with specific rewarding stimuli present (i.e., Conflict and Reward tasks) more rewarding than lower BAS Reward Responsiveness activity was (as indicated by positive affect following the tasks).

Significant partial correlations were revealed between negative affect following the Baseline task and Sensitivity to Punishment, $r(36) = .40$, $p < .05$, and between negative affect following the Baseline task and Neuroticism, $r(36) = .35$, $p < .05$. There was also a near significant correlation between negative affect following this same task and STAI, $r(36) = .30$, $p = .07$. The positive sign of these correlations relates to higher scores on these personality measures being associated with higher negative affect following performance of the Baseline task. The associations between these personality measures and negative affect were, although not significant (except for Neuroticism, $r(36) = .34$, $p > .05$), $p > .05$, in the same direction following the Punishment task as following the Baseline task and, again, although not significant, $p > .05$, were in the same direction but weaker still following the Reward task compared to following the Baseline and Punishment tasks (see Table 4.11).

Table 4.11

*Correlations between Positive and Negative Affect following the Four Tasks and Personality Measures, Age, and Sex*

| Affect | Task | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Positive | Baseline | -.11 | .14 | .06 | .24 | -.03 | .09 | -.08 | -.21 | .08 | .21 | .18 | .02 | .01 | .07 | -.40* |
| | Punishment | -.08 | .27 | .12 | .08 | -.03 | .11 | -.03 | -.02 | .01 | .19 | .12 | .07 | .03 | .09 | -.31 |
| | Reward | -.30 | .10 | .12 | .20 | .14 | .09 | -.10 | -.31 | .05 | .29 | .14 | .05 | .10 | .01 | -.22 |
| | Conflict | -.14 | .26 | .21 | .04 | -.10 | .13 | -.07 | -.12 | -.10 | .33* | -.03 | -.04 | .15 | .15 | -.23 |
| Negative | Baseline | .04 | -.10 | .19 | .18 | .39* | .14 | .08 | -.36* | .35* | .02 | .32* | .08 | .31 | .06 | -.19 |
| | Punishment | .06 | -.09 | .25 | .25 | .27 | .11 | -.16 | -.18 | .37* | -.26 | .22 | .21 | .04 | -.13 | .02 |
| | Reward | .07 | -.04 | .14 | .02 | .24 | -.06 | .03 | -.29 | .23 | -.15 | .20 | .04 | -.08 | -.19 | .00 |
| | Conflict | .12 | .02 | .02 | -.07 | .19 | -.05 | .17 | -.17 | .13 | -.12 | .07 | .15 | .16 | -.10 | .13 |
| Positive[a] | Baseline | -.10 | .12 | .15 | .23 | -.02 | .07 | -.15 | -.12 | .08 | — | .15 | .21 | .01 | .08 | — |
| | Punishment | -.06 | .26 | .19 | .05 | -.02 | .13 | -.07 | .07 | .01 | — | .09 | .23 | .03 | .10 | — |
| | Reward | -.28 | .07 | .17 | .17 | .18 | .20 | -.10 | -.24 | .09 | — | .15 | .19 | .14 | .03 | — |
| | Conflict | -.09 | .24 | .28 | -.01 | -.08 | .27 | -.08 | -.03 | -.08 | — | -.04 | .10 | .21 | .18 | — |
| Negative[a] | Baseline | .04 | -.10 | .23 | .18 | .40* | .10 | .04 | -.34* | .35* | — | .30 | .15 | .30 | .06 | — |
| | Punishment | .01 | -.05 | .26 | .29 | .25 | -.01 | -.21 | -.24 | .34* | — | .20 | .18 | -.01 | -.17 | — |
| | Reward | .05 | -.02 | .15 | .03 | .23 | -.17 | .00 | -.33* | .21 | — | .18 | .02 | -.11 | -.20 | — |
| | Conflict | .11 | .03 | -.01 | -.05 | .18 | -.07 | .18 | -.22 | .12 | — | .08 | .10 | .16 | -.11 | — |

*Note.* n = 40; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward;

P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]Partial correlations controlling for Lie scale score and Sex.

**p* < .05. ***p* < .01.

Potentially, these results suggest that higher BIS activity (as measured by the Sensitivity to Punishment scale and the STAI) was actually associated with finding the Baseline task the most punishing (especially when compared to the Reward and Conflict tasks) and that higher Neuroticism was actually associated with finding the Baseline and Punishment tasks the most punishing (when compared to the Reward and Conflict tasks). These results could help to explain some of the unexpected results obtained concerning associations between response inhibition and BIS measures and Neuroticism on and across tasks (see sections 4.3.1.3.1 and 4.3.1.4).

Partial correlations shown in Table 4.11 reveal that a higher Extraversion score was significantly related to lower negative affect following the Baseline task, $r(36) = -.34$, $p < .05$, and lower negative affect following the Reward task, $r(36) = -.33$, $p < .05$. It is clear from examination of these $r$ values that the negative association between Extraversion and negative affect was no stronger following the Reward task than it was following the Baseline task.

*4.3.1.6 Task order and associations between personality and response inhibition*

Table 4.12 shows correlations between the dependent measures of response inhibition on the three tasks performed in different orders (Punishment, Reward, and Conflict tasks) after the Baseline task and personality measures, age, and sex for the two groups that performed the tasks in different orders. There were no significant associations between age or sex and the two dependent measures of response inhibition on any of the three tasks for either group, $p > .05$. A higher STAI (i.e., BIS) score and a higher Neuroticism score were significantly related to a higher probability of inhibition (i.e., stronger inhibitory control) on the Punishment task, $r(21) = .45$, $p < .05$, and, $r(21) = .44$, $p < .05$, respectively, in line with prediction, but only for the group that performed the Punishment task before the Reward task. Near significant correlations were revealed between SSRT on the Punishment task and BAS Fun Seeking, $r(21) = -.43$, $p = .05$, and between SSRT on the Punishment task and Extraversion, $r(21) = -.43$, $p = .05$, only for the group that performed the Punishment task before the Reward task. The negative sign of these correlations relates to higher scores on these personality measures being associated with faster SSRT (i.e., stronger inhibitory control) on this task, contrary to prediction. However, the presence of these associations (all four of the ones mentioned above) on the Punishment task for this group only could, when coupled with the results obtained concerning affect following task performance (described in section 4.3.1.5), help to explain some of the unexpected results obtained concerning associations between response inhibition and personality measures on and across tasks (see sections 4.3.1.3.1 and 4.3.1.4).

In terms of associations between personality measures and response inhibition on the Reward task, examination of Table 4.12 shows that, a similar pattern of unexpected findings as initially revealed in Table 4.4 (both groups analysed together) was obtained when analysing separately the two groups that performed the tasks in different orders. A higher Sensitivity to Punishment (i.e., BIS) score was significantly related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task for the group that performed the Reward task before the Punishment task, $r(20) = -.63, p < .01$, and a slower SSRT (i.e., weaker inhibitory control) on this task for the other group (Punishment task before Reward task), $r(21) = .65, p < .01$. A higher STAI (i.e., BIS) score and a higher Neuroticism score were significantly related to a lower probability of inhibition on stop-trials, $r(20) = -.56, p < .01$, and, $r(20) = -.59, p < .01$, respectively, and a slower SSRT, $r(20) = .61, p < .01$, and, $r(20) = .50, p < .05$, respectively, on this task for the group that performed the Reward task before the Punishment task and were near significantly related to a slower SSRT on this task for the other group (Punishment task before Reward task), $r(21) = .37, p = .10$, and, $r(21) = .37, p < .10$, respectively. A higher Fear score was significantly related to a slower SSRT (i.e., weaker inhibitory control) on the Reward task for the group that performed the Punishment task before the Reward task, $r(21) = .50, p < .05$. Although the correlation between this personality measure and SSRT on this task was not significant for the other group (Reward task before Punishment task), $p > .05$, it was, however, found to be in the same, unexpected, direction.

Table 4.12

*Correlations between Measures of Response Inhibition on the Three Tasks Performed in Different Orders and Personality Measures, Age, and Sex for the Two Groups that Performed the Stop-signal Tasks in Different Orders*

| Task | Measure | Order | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Punishment | *P* (In) | P 1st [a] | .21 | .18 | .00 | .16 | .29 | .13 | .23 | .00 | .44* | -.29 | .45* | .01 | -.14 | -.03 | -.10 |
| | | R 1st [b] | .25 | .14 | .17 | -.15 | -.35 | .30 | .04 | .12 | -.34 | -.03 | -.21 | .02 | .20 | .33 | -.20 |
| | SSRT | P 1st [a] | -.23 | -.43 | -.36 | -.21 | -.02 | -.06 | -.09 | -.43 | -.21 | .01 | -.22 | .02 | .44* | .17 | -.10 |
| | | R 1st [b] | .01 | .02 | -.07 | -.18 | -.17 | -.25 | .16 | .26 | -.07 | -.32 | -.10 | -.04 | -.19 | -.19 | .08 |
| Reward | *P* (In) | P 1st [a] | .43 | .21 | .01 | -.19 | -.28 | -.05 | .32 | .07 | -.06 | .24 | -.11 | -.34 | -.14 | .23 | -.14 |
| | | R 1st [b] | .16 | .18 | -.01 | -.36 | -.63** | .25 | .07 | .52* | -.59** | -.28 | -.56** | -.15 | -.06 | .24 | -.10 |
| | SSRT | P 1st [a] | -.59** | -.45* | -.06 | .24 | .65** | .16 | -.35 | -.49* | .37 | -.24 | .37 | .50* | .27 | .04 | -.09 |
| | | R 1st [b] | .04 | -.01 | .32 | .25 | .40 | .27 | -.05 | -.30 | .50* | -.17 | .61** | .20 | .21 | .08 | -.05 |
| Conflict | *P* (In) | P 1st [a] | .13 | .03 | -.17 | .04 | -.15 | -.20 | .22 | .09 | .09 | .14 | .01 | -.26 | -.07 | -.07 | -.05 |
| | | R 1st [b] | .28 | .34 | .21 | .08 | -.24 | .44 | .23 | .19 | -.16 | -.27 | -.17 | -.01 | -.13 | .34 | -.27 |
| | SSRT | P 1st [a] | -.10 | -.25 | -.01 | .06 | .40 | .26 | -.25 | -.48* | .13 | .05 | .14 | .34 | .43* | .29 | -.13 |
| | | R 1st [b] | .02 | -.33 | -.09 | -.19 | .06 | -.34 | -.11 | .06 | .00 | .28 | .14 | .09 | .07 | -.33 | .10 |

*Note.* P 1st = group that performed Punishment task before Reward task; R 1st = group that performed Reward task before Punishment task; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]n = 21. [b]n = 20.

*$p < .05$. **$p < .01$.

A higher Extraversion score was significantly related to a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Reward task for the group that performed the Reward task before the Punishment task, $r(20) = .52, p < .05$, and a faster SSRT (i.e., stronger inhibitory control) on this task for the other group (Punishment task before Reward task), $r(21) = -.49, p < .05$. A higher BAS Drive and a higher BAS Fun Seeking score were significantly related to a faster SSRT on the Reward task, $r(21) = -.59, p < .01$, and, $r(21) = -.45, p < .05$, respectively, only for the group that performed the Punishment task before the Reward task. There was also a near significant correlation between the other measure of response inhibition, probability of inhibition on stop-trials, on this same task and BAS Drive score, $r(21) = .43, p = .05$, again, only for the group that performed the Punishment task before the Reward task. The positive sign of this correlation reflects a higher score on the BAS Drive scale being related to a higher probability of inhibition on stop-trials on the Reward task. The presence of these associations (all three of the ones mentioned above) on the Reward task for this group only could, when coupled with the results obtained concerning affect following task performance (described in section 4.3.1.5), help to explain some of the unexpected results obtained concerning associations between response inhibition and personality measures on and across tasks (see sections 4.3.1.3.1 and 4.3.1.4).

A higher Extraversion score was significantly related to a faster SSRT (i.e., stronger inhibitory control) on the Conflict task for the group that performed the Punishment task before the Reward task, $r(21) = -.48, p < .05$. There was a near significant correlation between the other measure of response inhibition, probability of inhibition on stop-trials, on this same task and Sensitivity to Reward for the other group (Reward task before Punishment task), $r(20) = .44, p = .06$. The positive sign of this correlation reflects a higher score on the Sensitivity to Reward scale being associated with a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Conflict task. Neither of these two correlations was revealed as significant, or near significant, in Table 4.4 (both groups analysed together).

Significant correlations were revealed for SSRT on the Punishment and Conflict tasks and SOGS score, $r(21) = .44, p < .05$, and, $r(21) = .43, p < .05$, respectively, for the group that performed the Punishment task before the Reward task. The positive sign of these correlations relates to a higher score on the SOGS being associated with a slower SSRT (i.e., weaker inhibitory control) on these two tasks.

*4.3.1.7 Sex and associations between personality and response inhibition*

Table 4.13 shows correlations between the dependent measures of response inhibition on the four stop-signal tasks and personality measures and age for both males and females. Due to the presence of significant correlations between the EPQ-RS Lie scale and probability of inhibition on stop-trials on the Punishment task for the male group, $r(20) = -.46, p < .05$, and between age and this same measure of response inhibition on the Baseline and Reward tasks for the female group, $r(21) = .43$, $p < .05$, and, $r(21) = .46, p < .05$, respectively, partial correlations, controlling for Lie score and age, between the dependent measures of response inhibition on the four tasks and personality measures for both males and females are shown in Table 4.14.

Examination of Table 4.14 shows that, in line with prediction, a higher BIS score was significantly related to a higher probability of inhibition on stop-trials, $r(17) = .49, p < .05$, and a faster SSRT, $r(17) = -.51, p < .05$, (i.e., stronger inhibitory control) on the Baseline task. However, these significant correlations were obtained for the female group only. Also in line with prediction, a higher BIS score was significantly related to a higher probability of inhibition on stop-trials, $r(17) = .57, p < .05$, and near significantly related to a faster SSRT, $r(17) = -.40, p < .10$, on the Punishment task. However, again these significant (or near significant) correlations were obtained for the female group only.

Table 4.13

*Correlations between Measures of Response Inhibition on the Four Tasks and Personality Measures and Age for Both Sexes*

| Task | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | *P* (In) | M[a] | .25 | .11 | -.05 | -.35 | .01 | .05 | .43 | .05 | -.27 | -.27 | -.12 | .13 | -.38 | .12 |
| | | F[b] | .14 | .00 | .19 | .29 | -.11 | -.09 | .07 | -.11 | .16 | .09 | .24 | -.08 | .22 | .43* |
| | SSRT | M[a] | -.33 | -.31 | .07 | .32 | .01 | .07 | -.39 | -.09 | .12 | .05 | -.09 | .08 | .55* | -.09 |
| | | F[b] | .07 | .09 | -.34 | -.47* | -.12 | .17 | .09 | .26 | -.21 | -.03 | -.23 | -.04 | -.01 | -.04 |
| Punishment | *P* (In) | M[a] | .34 | .23 | .00 | -.36 | .07 | .28 | .17 | .30 | .02 | -.46* | .01 | .12 | -.14 | -.05 |
| | | F[b] | .08 | .02 | .26 | .44* | .04 | .04 | .15 | -.09 | .25 | .08 | .35 | .10 | .26 | .28 |
| | SSRT | M[a] | -.25 | -.16 | -.03 | .02 | -.07 | -.15 | .09 | -.17 | -.15 | -.17 | -.24 | .14 | .18 | -.01 |
| | | F[b] | -.02 | -.26 | -.42 | -.39 | -.14 | -.21 | -.02 | .05 | -.14 | -.13 | -.11 | -.13 | .07 | -.01 |
| Reward | *P* (In) | M[a] | .29 | .15 | -.03 | -.49* | -.33 | .12 | .20 | .40 | -.39 | -.21 | -.48* | -.09 | -.27 | -.03 |
| | | F[b] | .30 | .22 | .09 | -.06 | -.54* | .03 | .18 | .30 | -.21 | .15 | -.20 | -.27 | .11 | .46* |
| | SSRT | M[a] | -.16 | -.10 | .32 | .41 | .50* | .40 | -.23 | -.47* | .46* | -.32 | .52* | .30 | .53* | .15 |
| | | F[b] | -.40 | -.39 | -.03 | .08 | .57** | -.04 | -.15 | -.23 | .42 | -.09 | .48* | .46* | -.13 | -.02 |
| Conflict | *P* (In) | M[a] | .27 | .19 | -.03 | -.33 | -.25 | .21 | .36 | .33 | -.23 | -.24 | -.43 | -.17 | -.29 | .04 |
| | | F[b] | .11 | .10 | .16 | .44* | -.07 | -.16 | .09 | .03 | .29 | .11 | .30 | -.02 | .19 | .17 |
| | SSRT | M[a] | -.18 | -.45* | .09 | .33 | .38 | -.14 | -.48* | -.43 | .18 | .24 | .29 | .35 | .47* | -.12 |
| | | F[b] | .04 | -.10 | -.22 | -.42 | .08 | .13 | .07 | .04 | -.09 | .03 | -.01 | .17 | .04 | .17 |

*Note.* M = male group; F = female group; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]n = 20. [b]n = 21.

*$p < .05$. **$p < .01$.

Table 4.14

*Partial Correlations[a] between Measures of Response Inhibition on the Four Tasks and Personality Measures for Both Sexes*

| Task | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | STAI | Fear | SOGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline | *P* (In) | M[b] | .24 | -.04 | -.12 | -.36 | -.03 | -.15 | .39 | .01 | -.37 | -.21 | .05 | -.46 |
| | | F[c] | .14 | -.04 | .12 | .49* | -.01 | -.26 | -.09 | -.14 | .26 | .28 | -.11 | .16 |
| | SSRT | M[b] | -.34 | -.31 | .11 | .33 | .02 | .12 | -.38 | -.08 | .14 | -.08 | .10 | .58* |
| | | F[c] | .08 | .10 | -.34 | -.51* | -.13 | .19 | .11 | .26 | -.22 | -.23 | -.04 | -.01 |
| Punishment | *P* (In) | M[b] | .32 | .04 | -.03 | -.39 | -.03 | .00 | .09 | .29 | -.13 | -.14 | -.07 | -.23 |
| | | F[c] | .06 | .00 | .22 | .57* | .11 | -.03 | .07 | -.10 | .31 | .37 | .09 | .23 |
| | SSRT | M[b] | -.28 | -.27 | -.05 | .03 | -.10 | -.32 | .06 | -.19 | -.21 | -.30 | .08 | .16 |
| | | F[c] | .02 | -.24 | -.40 | -.40 | -.15 | -.28 | -.04 | .03 | -.15 | -.11 | -.13 | .05 |
| Reward | *P* (In) | M[b] | .27 | .07 | -.04 | -.49* | -.38 | -.01 | .17 | .39 | -.49* | -.58* | -.19 | -.30 |
| | | F[c] | .31 | .21 | -.02 | .06 | -.52* | -.10 | .04 | .35 | -.16 | -.22 | -.33 | .05 |
| | SSRT | M[b] | -.19 | -.33 | .28 | .44 | .49* | .27 | -.34 | -.56* | .42 | .47* | .24 | .51* |
| | | F[c] | -.40 | -.39 | -.01 | .10 | .58** | -.08 | -.17 | -.25 | .42 | .48* | .46* | -.16 |
| Conflict | *P* (In) | M[b] | .26 | .09 | -.08 | -.33 | -.31 | .09 | .32 | .31 | -.32 | -.53* | -.28 | -.34 |
| | | F[c] | .08 | .08 | .11 | .51* | -.03 | -.21 | .05 | .04 | .33 | .31 | -.02 | .19 |
| | SSRT | M[b] | -.17 | -.39 | .17 | .34 | .44 | .00 | -.45 | -.41 | .26 | .38 | .47* | .54* |
| | | F[c] | .03 | -.12 | -.27 | -.41 | .13 | .10 | .02 | .04 | -.06 | -.01 | .16 | .01 |

*Note.* M = male group; F = female group; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]The following variables were controlled for: Lie scale score and age. [b]n = 20. [c]n = 21.

*$p < .05$. **$p < .01$.

In terms of associations between personality measures and response inhibition on the Reward task, examination of Table 4.14 shows that, a similar pattern of unexpected findings as initially revealed in Table 4.4 (both groups analysed together) was obtained when analysing males and females separately. A higher Sensitivity to Punishment (i.e., BIS) score was significantly related to a lower probability of inhibition on stop-trials on the Reward task for the female group, $r(17) = -.52$, $p < .05$, and a slower SSRT (i.e., weaker inhibitory control) on the Reward task for the female group, $r(17) = .57$, $p < .01$, and the male group, $r(16) = .49$, $p < .05$, and a higher STAI (i.e., BIS) score was significantly related to a lower probability of inhibition on stop-trials on the Reward task for the male group, $r(16) = -.58$, $p < .05$, and a slower SSRT on the Reward task for the male group, $r(16) = .47$, $p < .05$, and the female group, $r(17) = .48$, $p < .05$. A higher Neuroticism score was significantly related to a lower probability of inhibition on stop-trials on this same task for the male group, $r(16) = -.49$, $p < .05$, and was near significantly related to a slower SSRT on this task for the male group, $r(16) = .42$, $p = .08$, and the female group, $r(17) = .42$, $p = .07$. A higher Fear score was significantly related to a slower SSRT on this same task for the female group only, $r(17) = .46$, $p < .05$. However, although the correlation between this personality measure and SSRT on the Reward task was not significant for the male group, $p > .05$, it was in the same, unexpected, direction.

The partial correlations obtained between measures of response inhibition on the Reward task and the BIS scale were consistent with the unexpected findings revealed for the other BIS measures but only for the male group: a higher score on the BIS scale was found to be significantly related to a lower probability of inhibition on stop-trials, $r(16) = -.49$, $p < .05$, and was near significantly related to a slower SSRT, $r(16) = .44$, $p = .07$. This could be why $r$ values for these correlations initially revealed in Table 4.4 (both groups analysed together) did not reach significance, $p > .05$. A higher BAS Drive score and a higher BAS Fun Seeking score were near significantly related to a faster SSRT on the Reward task, $r(17) = -.40$, $p = .09$, and, $r(17) = -.39$, $p = .10$, for the female group only. However, although the correlations between these personality measures and SSRT on this task were not significant for the male group, $p > .05$, they were in the same, unexpected, direction.

Examination of Table 4.14 shows that associations between personality measures and response inhibition on the Conflict task were quite different between sexes. A higher BIS scale score was significantly related to a higher probability of inhibition on stop-trials, $r(17) = .51, p < .05$, and near significantly related to a faster SSRT, $r(17) = -.41, p = .09$, (i.e., stronger inhibitory control) on the Conflict task, in line with prediction, for the female group only. In contrast, a higher STAI (i.e., BIS) score was significantly related to a lower probability of inhibition on stop-trials, $r(16) = -.53, p < .05$, a higher Fear score was significantly related to a slower SSRT, $r(16) = .47, p < .05$, and a higher Sensitivity to Punishment (i.e., BIS) score was near significantly related to a slower SSRT, $r(16) = .44, p = .07$, on the Conflict task, for the male group, contrary to prediction.

Table 4.14 shows that significant correlations were revealed for SSRT on the Baseline, Reward, and Conflict tasks and SOGS score, $r(16) = .58, p < .05$, $r(16) = .51, p < .05$, and, $r(16) = .54, p < .05$, respectively, for the male group. The positive sign of these correlations relates to a higher score on the SOGS being associated with a slower SSRT (i.e., weaker inhibitory control) on these three tasks. A higher SOGS score was also near significantly related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Baseline task, , $r(16) = -.46, p = .06$, for the male group.

*4.3.2 Q-task*

One case with an extremely high z score (beyond the $p = .001$ criterion of 3.29, two-tailed) on EPQ-RS Lie was found to be a univariate outlier. Since the Lie scale is designed for the revelation of dishonesty, the case with the extremely high Lie scale score was deleted, leaving 41 cases for analyses. Table 4.15 shows correlations between Q-inhibition and personality measures.

Examination of Table 4.15 shows that there were no significant associations between age or sex and Q-inhibition, $p > .05$. As expected, a significant correlation was obtained for Q-inhibition and a measure of BIS activity. Consistent with prediction, a higher score on the BIS scale was related to a greater Q-inhibition, $r(41) = .37$, $p < .05$. However, no other measure of BIS activity (Sensitivity to Punishment scale of the SPSRQ, STAI trait anxiety) was significantly related to Q-inhibition, $p > .05$, contrary to prediction.

Table 4.15

*Correlations between Q-inhibition on the Q-task and Personality Measures, Age, and Sex*

| Measure | Q-inhibition |
|---|---|
| BAS Drive | -.15 |
| BAS Fun Seeking | -.15 |
| BAS Reward Responsiveness | .01 |
| BIS | .37* |
| Sensitivity to Punishment | .15 |
| Sensitivity to Reward | -.11 |
| Psychoticism | -.26 |
| Extraversion | -.18 |
| Neuroticism | -.07 |
| Lie | .16 |
| State-Trait Anxiety Inventory | .00 |
| FSS Fear | .11 |
| South Oaks Gambling Screen | -.03 |
| Age | -.25 |
| Sex | .16 |

*Note.* n = 41.
$^*p < .05$.

*4.3.3 Associations between inhibition measures on and between experimental tasks*

Table 4.16 shows correlations between the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) on all four stop-signal tasks and Q-inhibition. The two dependent measures of response inhibition were appropriately significantly related to one another on each of the four different stop-signal tasks (i.e., higher probability of inhibition on stop-trials was related to slower SSRT). Neither measure of response inhibition on any of the stop-signal tasks was significantly related to Q-inhibition, $p > .05$.

Table 4.16

*Correlations between Inhibition Measures on the Stop-signal Tasks and the Q-task*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Baseline *P* (In) | — | | | | | | | | |
| 2. Baseline SSRT | -.67** | — | | | | | | | |
| 3. Punishment *P* (In) | .68** | -.56** | — | | | | | | |
| 4. Punishment SSRT | -.16 | .59** | -.41** | — | | | | | |
| 5. Reward *P* (In) | .66** | -.31* | .61** | -.06 | — | | | | |
| 6. Reward SSRT | -.40** | .39* | -.24 | .30 | -.59** | — | | | |
| 7. Conflict *P* (In) | .59** | -.32* | .72** | -.25 | .73** | -.39* | — | | |
| 8. Conflict SSRT | -.28 | .48** | -.45** | .51** | -.37* | .45** | -.66** | — | |
| 9. Q-(In) | -.02 | -.13 | -.06 | -.01 | -.04 | -.07 | -.07 | -.08 | — |

*Note.* n = 42; Baseline = Baseline stop-signal task; Punishment = Punishment stop-signal task; Reward = Reward stop-signal task; Conflict = Conflict stop-signal task; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; Q-(In) = Q-inhibition.

**p* < .05. ***p* < .01.

## 4.4 Discussion

The purpose of the present study was to show that inhibitory control on the stop-signal task could be modified using different response contingencies and that these modifications would be related to individual differences in reward and punishment sensitivity (i.e., personality). Toward this end, a 'standard' task was used to measure baseline motor inhibition without specific motivational stimuli, a 'punishment' task with specific punishing motivational stimuli included was used to create an avoidance situation, a 'reward' task with specific rewarding motivational stimuli included was used to create an approach situation and a 'conflict' task with both specific rewarding and punishing motivational stimuli included was used to create an approach-avoidance conflict situation. Consistent with expectations and with the findings of previous research using the same four tasks (Experiments 2 and 3 of chapter 3; sections 3.2 and 3.3, respectively), the results obtained in the present study provided support for the idea that inhibitory control on the stop-signal task can be modified using different response contingencies. The results also provided support for the reputation of the Q-task as a face valid, behavioural assessment device for the measurement of BIS functioning (see Pickering et al., 1997). Consistent with prediction and with previous research (e.g., Newman et al., 1997), higher self-reported BIS activity (assessed by the BIS scale) was associated with greater Q-inhibition (the degree to which the Q elicits behavioural inhibition in the test phase).

Also consistent with prediction, dependent measures of stop-signal task performance (probability of inhibition on stop-trials, SSRT, MRT on go-trials, and go-trial response accuracy) differed across tasks in an almost identical manner as found in Experiment 3, chapter 3 (see section 3.3). One of the only differences between the findings of the two studies was that, in Experiment 3, participants displayed a faster estimated time to inhibit a response (i.e., SSRT was faster) on the Conflict task compared to on the Baseline task, whereas, in the present study, participants displayed no difference in SSRT between these two tasks. However, this finding in Experiment 3 was unexpected and was not supported by a significant mean difference in participants' probability of inhibition on stop-trials (the other measure of response inhibition) between these two tasks and so it was concluded that inhibitory control was similar on the Baseline task compared to on the Conflict task, consistent with prediction and with the findings of the present study. Another difference between the findings of the two studies was that, in the present study, participants displayed a faster MRT on go-trials on the Reward task compared to on the Conflict task, whereas, in Experiment 3, participants displayed no difference in MRT on go-trials between these two tasks.

However, although, in Experiment 3, there was no significant difference in MRT on go-trials between these two tasks, the mean difference was in the same direction as found in the present study (i.e., faster MRT on go-trials on the Reward task than on the Conflict task). It is possible that the smaller sample size used in Experiment 3 (n = 34) was simply not large enough to result in the mean difference reaching significance as it did in the present study (n = 42). Other than the two differences just discussed, the results obtained in the present study concerning task differences in dependent measures of stop-signal task performance have shown strong and reliable replication of the results obtained in previous research using the same four tasks.

Whereas Oosterlaan and Sergeant's (1997) study did not allow them to determine the effects of rewarding and punishing contingencies as such (by not including a condition in which there were no contingencies), leaving open the possibility that response contingencies affect inhibitory control on the stop-signal task relative to no contingencies, the present study produced evidence showing that different response contingencies did affect inhibitory control on the stop-signal task relative to no specific motivational stimuli. Specific rewarding stimuli (on the Reward task) had the expected effect of reducing participants' probability of inhibition on stop-trials (i.e., weakening their inhibitory control) compared to on the Baseline (no specific motivational stimuli) task and specific punishing stimuli (on the Punishment task) had the expected effect of increasing participants' probability of inhibition on stop-trials as well as speeding-up their estimated time to inhibit a response (i.e., SSRT; strengthening their inhibitory control) compared to on the Baseline task.

Contrary to Rodriguez-Fornells et al.'s (2002) findings that inhibitory control was stronger on their approach-avoidance conflict situation task compared to on the standard task, inhibitory control was found to be similar on the Conflict task in the present study compared to on the Baseline (standard) task, consistent with prediction. Rodriguez-Fornells et al.'s reversal of the assignment of responses to the two subsets of stimulus letters in their two different conditions, in an attempt to avoid practise effects, resulted in an unreliable comparison between the two tasks. In the present study, the assignment of responses to the two subsets of stimulus letters were kept the same for all four conditions (tasks) to allow for a more reliable comparison between tasks. The order of task administration was counterbalanced across participants in an attempt to control for any possible confounding extraneous variables (e.g., practise effects) and then any order effects were investigated. No task order effects were revealed, consistent with previous research using the same four tasks (Experiments 2 and 3 of chapter 3; sections 3.2 and 3.3, respectively).

*4.4.1 Inhibitory control on the stop-signal tasks related to personality*

It was predicted that, since the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), higher self-reported BAS activity and Extraversion should be associated with weaker inhibitory control on each of the four tasks and, conversely, higher self-reported BIS activity, Fear, and Neuroticism should be associated with stronger inhibitory control on each of the four tasks. Although the confirmatory analyses, investigating associations between personality measures and measures of inhibitory control for all participants taken together, revealed no relation between personality and inhibitory control on the Baseline (standard) task, contrary to prediction, evidence was produced in the exploratory analyses showing that a higher score on the BIS scale was related to stronger inhibitory control (based on both measures of response inhibition) on the Baseline task, consistent with prediction, for the female group only.

The Baseline task was similar to that used by Avila and Parcet (2001). Avila and Parcet demonstrated that high BAS and low BIS were associated with impaired inhibitory control on the stop-signal task in a sample of female undergraduates. The present study, therefore, produced evidence in support of Avila & Parcet's finding that a low BIS was associated with weaker inhibitory control on the standard stop-signal task for females. However, no evidence was obtained to suggest that a high BAS was associated with impaired inhibitory control on the Baseline (i.e., standard) task for females (or males), contrary to Avila & Parcet's findings and contrary to prediction based on their findings. It required the addition of specific motivational stimuli to the standard task to reveal any associations between BAS activity and response inhibition in the present study. The apparent lack of associations between personality measures and inhibitory control on the standard task suggests that although, as argued by Avila & Parcet, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (p. 983), with no specific motivational stimuli present to reinforce these rewarding and punishing cues (as in the standard task), they might simply be inadequately potent to significantly tap into the BIS (especially for males) and the BAS.

More gender differences were revealed when analysing response inhibition related to personality on the Punishment and Conflict tasks. Again, although the confirmatory analyses revealed no relation between BIS activity, Fear, or Neuroticism and inhibitory control on the Punishment or Conflict tasks, contrary to prediction, exploratory analyses produced evidence showing that a higher score on the BIS scale was related to stronger inhibitory control (based on both measures of response inhibition) on both of these tasks, consistent with prediction, for the female group only. In contrast, a higher BIS activity (assessed by the STAI and the Sensitivity to Punishment scale) and higher Fear were found to relate to a weaker inhibitory control on the Conflict task, contrary to prediction, for the male group. However, with regards to response inhibition on the Punishment task, exploratory analyses also produced evidence showing that a higher BIS activity (assessed by the STAI) and higher Neuroticism were related to a stronger inhibitory control (based on probability of inhibition on stop-trials) on this task, consistent with prediction, for the group that performed the Punishment task before the Reward task. This group comprised both males and females, suggesting that the order in which the reinforcement tasks were performed, and not gender alone, affected associations between these personality measures and response inhibition on the Punishment task. Confirmatory analyses produced no evidence to support the predictions that higher self-reported BAS activity and Extraversion should be associated with weaker inhibitory control on the Punishment task. This again suggests that although, as argued by Avila and Parcet (2001), the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (p. 983), with no specific motivational stimuli present to reinforce this rewarding cue (as in the standard and Punishment tasks), it might simply be too weak to significantly tap into the BAS.

The specific motivational stimuli present on the Reward and Conflict tasks were, apparently, reinforcing enough to produce associations between self-reported BAS activity (on the Conflict and

Reward tasks), Extraversion (on the Reward task only), and response inhibition. However, confirmatory analyses revealed that a higher BAS activity (assessed by the BAS Fun Seeking scale) was related to a stronger inhibitory control (based on SSRT) on the Conflict task, contrary to prediction, and a higher BAS activity (assessed by the BAS Drive scale) and higher Extraversion were related to a stronger inhibitory control (based on both measures of response inhibition) on the Reward task, also contrary to prediction. The specific rewarding stimuli present on the Reward task was also, apparently, reinforcing enough to produce associations between self-reported BIS activity, Fear, Neuroticism, and response inhibition. Contrary to prediction, confirmatory analyses revealed that a higher BIS activity (assessed by the Sensitivity to Punishment scale and the STAI), higher Fear, and higher Neuroticism were related to weaker inhibitory control (based on both measures of response inhibition, except for Fear which was based on SSRT only) on the Reward task. These unexpected findings could possibly be explained in terms of participants' reinforcement expectancies, discussed below (section 4.4.3).

*4.4.2 Stop-signal task differences on inhibitory control related to personality*

It was predicted that, due to the presence of specific punishing stimuli, higher self-reported BIS activity, Fear, and Neuroticism should be more strongly associated with stronger inhibitory control on the Punishment and Conflict tasks than on the Baseline and Reward tasks. Evidence was produced showing that higher self-reported Neuroticism was more strongly associated with higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Punishment task than on the Baseline task (see Figure 4.13), consistent with prediction. However, similar evidence was not produced based on the other measure of response inhibition, SSRT, and no evidence was produced to support the prediction that higher self-reported BIS activity and Fear should be more strongly associated with stronger inhibitory control on the Punishment task than on the Baseline task. Evidence was produced showing that higher self-reported BIS activity (assessed by all BIS measures employed), Fear, and Neuroticism were more strongly associated with higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Punishment task than on the Reward task (see Figures 4.6, 4.9, 4.13, 4.17, and 4.19), consistent with prediction. In terms of the other measure of response inhibition, SSRT, similar findings were revealed when comparing these two tasks.

Evidence was produced showing that higher self-reported BIS activity (assessed by all BIS measures employed except for the BIS scale of the BIS/BAS Scales), Fear, and Neuroticism were more strongly associated with a faster estimated time to inhibit a response (i.e., faster SSRT; stronger inhibitory control) on the Punishment task than on the Reward task (see Figures 4.11, 4.15, 4.18, and 4.20), consistent with prediction. However, what was actually expected, based on RST, Arousal theory, and the conceptualisation of the stop-signal as a punishment cue associated with response inhibition (Avila & Parcet, 2001), was that higher self-reported BIS activity, Fear, and Neuroticism would be associated with stronger inhibitory control on all four tasks and that by introducing specific punishing stimuli (thus reinforcing the stop-signal as a punishment cue) these associations would become even stronger on the Punishment and Conflict tasks compared to on the other two tasks. Instead, the results showed that, contrary to expectations, higher scores on these personality measures were more strongly associated with weaker inhibitory control on the Reward task than they were associated with stronger inhibitory control on the Punishment task.

Evidence was produced showing that higher self-reported BIS activity (assessed by the BIS scale of the BIS/BAS Scales) was more strongly associated with higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Conflict task than on the Reward task (see Figure 4.6), consistent with prediction. However, similar evidence was not produced based on the other measure of response inhibition, SSRT, and, again, contrary to expectations, a higher score on this personality measure was actually more strongly associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task than it was associated with a higher probability of inhibition on stop-trials on the Conflict task. Consistent with these unexpected findings, evidence was produced showing that higher self-reported BIS activity (assessed by the Sensitivity to Punishment scale and the STAI) and Neuroticism were less strongly associated with lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Conflict task (specific rewarding and punishing stimuli present) than on the Reward task (see Figures 4.9, 4.17, and 4.13, respectively). In terms of the other measure of response inhibition, SSRT, higher self-reported BIS activity (assessed by the STAI) was less strongly associated with a slower estimated time to inhibit a response (i.e., slower SSRT; weaker inhibitory control) on the Conflict task than on the Reward task (see Figure 4.18). In a way, these findings do provide support for the prediction that, due to the presence of specific punishing stimuli, higher self-reported BIS activity and Neuroticism should be more strongly associated with stronger inhibitory control on the Conflict task than on the Reward task. However, caution must be taken in this interpretation since, again, the results seem to suggest that higher scores on these personality measures appeared to be more associated with weaker inhibitory control on the Reward task than they were associated with inhibitory control on the Conflict task, contrary to expectations.

Yet more unexpected findings included higher self-reported BIS activity (assessed by the Sensitivity to Punishment scale and the STAI) being more strongly associated with a slower estimated time to inhibit a response (i.e., slower SSRT; weaker inhibitory control) on the Conflict task compared to on the Baseline task (see Figures 4.11 and 4.18, respectively), contrary to prediction, and higher self-reported BIS activity (assessed by the Sensitivity to Punishment scale and the STAI) and Fear being associated with weaker inhibitory control (based on both measures of response inhibition) on the Reward task compared to on the Baseline task, contrary to prediction. Also, higher self-reported BIS activity (assessed by the Sensitivity to Punishment scale and the STAI) was associated with weaker inhibitory control (based on both measures of response inhibition) on the Conflict task compared to on the Punishment task and higher self-reported Fear was associated with a slower estimated time to inhibit a response (i.e., slower SSRT; weaker inhibitory control) on the Conflict task compared to on the Punishment Task (see Figures 4.9, 4.11, 4.17, 4.18, and 4.20). According to the separable subsystems hypothesis, responses to reward should be the same at all levels of Anx (see Corr, 2001, 2002b). It was, therefore, predicted that associations between BIS activity and measures of response inhibition should not differ when comparing the Reward task with the Baseline task or when comparing the Punishment task with the Conflict task, since the only difference between these pairs of tasks was the presence or absence of specific rewarding, not punishing, stimuli. Obtaining evidence to the contrary suggests that either responses to reward were not the same at all levels of Anx or it was not just the level of reward that differed between these pairs of tasks but also the level of punishment, in some unknown way (see below, section 4.4.3, for a possible explanation).

Altogether, the results obtained concerning associations between, and task differences on associations between, BIS activity, Fear, and Neuroticism and response inhibition on the four stop-signal tasks suggest that while higher reactivity in these personality dimensions was more related, as expected, to stronger inhibitory control in the presence of specific punishing stimuli only than in the presence of no specific motivational stimuli and than in the presence of specific rewarding stimuli only, higher reactivity in these personality dimensions was related to weaker inhibitory control in the presence of specific rewarding stimuli, contrary to expectations.

It was predicted that, due to the presence of specific rewarding stimuli, higher self-reported BAS activity and Extraversion should be more strongly associated with weaker inhibitory control on the Reward and Conflict tasks than on the Baseline and Punishment tasks. Evidence was produced showing that higher self-reported BAS activity (assessed by the BAS Reward Responsiveness scale and the Sensitivity to Reward scales) were more strongly associated with a slower estimated time to inhibit a response (i.e., slower SSRT; weaker inhibitory control) on the Reward task compared to on the Punishment task (see Figures 4.8 and 4.12), consistent with prediction. However, similar evidence was not produced based on the other measure of response inhibition, probability of inhibition on stop-trials, and these were the only personality scales to produce results consistent with prediction concerning associations between BAS activity and response inhibition.

Evidence was produced showing that higher self-reported BAS activity (assessed by the BAS Drive scale of the BIS/BAS scales) was more strongly associated with a faster estimated time to inhibit a response (i.e., faster SSRT; stronger inhibitory control) on the Reward task compared to on the

Conflict Task and higher self-reported BAS activity (assessed by the Sensitivity to Reward scale) was more strongly associated with a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the Punishment task compared to on the Baseline task (see Figures 4.7 and 4.10, respectively), contrary to prediction. According to the separable subsystems hypothesis, responses to punishment should be the same at all levels of Imp (see Corr, 2001, 2002b). It was, therefore, predicted that associations between BAS activity and measures of response inhibition should not differ when comparing the Punishment task with the Baseline task or when comparing the Reward task with the Conflict task, since the only difference between these pairs of tasks was the presence or absence of specific punishing, not rewarding, stimuli. Obtaining evidence to the contrary suggests that either responses to punishment were not the same at all levels of Imp or it was not just the level of punishment that differed between these pairs of tasks but also the level of reward, in some unknown way (see below for a possible explanation). Evidence was also produced showing that higher self-reported Extraversion was more strongly associated with stronger inhibitory control (based on both measures of response inhibition) on the Reward task compared to on the Baseline task, contrary to prediction.

*4.4.3 Possible reasons for unexpected results*

Corr (2001) has indicated the importance of assessing levels of subjective reward in any study employing Gray's RST to investigate reactions to rewarding and punishing situations to ensure that manipulations of motivation (in particular appetitive; see Corr 2002a) are effective. It is possible that putative appetitive tasks may elicit frustrative non-reward (aversive motivation) in certain participants who have high initial expectations of reward, leading to apparently theoretically inconsistent relationships between reactions to (assumed) rewarding situations and BAS activity. This idea provides one possible explanation for the unexpected findings concerning inhibitory control, BAS activity, and Extraversion in the present study. It is possible that, for some participants (i.e., high BAS Drive and high Extraversion), the specific rewarding stimuli present on the Reward task (and the Conflict task) was not as rewarding as they expected it to be, resulting in frustrative non-reward leading to avoidance of the frustrating stimuli (i.e., the specific rewarding stimuli present on go-trials) and, thus, stronger inhibitory control on this task.

Unfortunately, participants' thoughts on how rewarding they expected the tasks to be and how rewarding they actually perceived them to be before and after task performance was not measured in the present study. However, participants did complete a PANAS before and after performance of each of the tasks, providing a measure of mood (positive and negative affect) induced by task performance. Exploratory analyses revealed that a higher score on the BAS Drive scale was related to a lower positive affect following performance of the Reward task. Also, although not significant, there was a trend toward a higher Extraversion score being related to a lower positive affect following performance of this same task. Interestingly, these were the two personality measures that produced results inconsistent with predictions concerning relations between BAS activity, Extraversion and inhibitory control on the Reward task. In contrast, a higher score on the BAS Reward Responsiveness scale was related to a higher positive affect following performance of the Conflict task and, although not significant, there was a trend toward the same association on the Reward task. Also, although not significant, there was a trend toward a higher Sensitivity to Reward score being related to a higher positive affect following performance of these same two tasks. Interestingly again, these were the two personality measures that produced results more in line with predictions concerning relations between BAS activity and inhibitory control on the Reward task (at least, in comparison to associations on the Punishment task).

Clearly, scores on the PANAS do not provide evidence of initial expectations compared to actual perceived experiences. This is something that could be investigated in a future study using the four stop-signal tasks. It has been argued that 'participant-perceived reward needs to be equal to or greater than expected levels of reward for appetitive manipulations to be considered effective and for positive relationships between BAS traits and actual reactions to reward to be observed' (Kambouropoulos & Staiger, 2004, p. 1155). Kambouropoulos and Staiger assessed levels of reinforcement expectancies in relation to two behavioural tasks, assumed to tap into BIS/BAS functioning, using two 10-cm visual analogue scales. One scale was administered immediately prior to task performance and provided a measure of expected reward (i.e., "how rewarding do you expect the task to be?") and the second was administered immediately following task completion assessing actual perceived reward (i.e., "how rewarding did you find the task?"). This same method could be employed to assess levels of reinforcement expectancies in relation to the four stop-signal tasks in an attempt to investigate further some of the unexpected findings obtained in the present study.

Exploratory analyses also revealed that a higher BAS Drive score was related to a stronger inhibitory control on the Reward task but only for the group that performed the Punishment task before the Reward task. It could be that, after performing the Punishment task, high BAS Drive participants expected the Reward task to be highly rewarding in comparison to the task they just completed (i.e., the Punishment task). Then, when they found that the specific rewarding stimuli present on the Reward task did not meet with their high initial expectations, this elicited frustrative non-reward (aversive motivation) resulting in stronger inhibitory control. In contrast, expectations for reward may not have been so high before the Reward task for the other group since they had not just completed the Punishment task, and so the frustration experienced by this group on the Reward task would not have been so intense (or may not have been experienced at all) compared to that experienced by the group that performed the Punishment task before the Reward task. This finding indicates that any future study investigating levels of reinforcement expectancies in relation to the four stop-signal tasks should counterbalance the order of task administration (as in the present study) and needs to examine differences between the two groups that perform the tasks in different orders.

It is possible that reinforcement expectancies could also be used to explain some of the unexpected findings obtained concerning associations between BIS activity, Fear, Neuroticism and response inhibition in the present study. Just as it is theoretically possible for the omission of expected reward to elicit frustrative non-reward (aversive motivation), as discussed above, it is also possible, in a symmetrical manner, for the omission of expected punishment to elicit relief of non-punishment (appetitive motivation). For some participants (i.e., high BIS, high Neuroticism, and high Fear), the

Reward task (and the Conflict task) might not have been as punishing as they expected it to be, resulting in relief of non-punishment leading to approach behaviour on go-trials (i.e., the specific rewarding stimuli) and, thus, weaker inhibitory control on this task. Exploratory analyses revealed that higher BIS activity (assessed by the Sensitivity to Punishment and STAI scales) and higher Neuroticism were related to a higher negative affect following performance of the Baseline task and that higher Neuroticism was also related to a higher negative affect following performance of the Punishment task. Interestingly, higher scores on measures of these personality dimensions were not related to a higher negative affect following performance of the Reward or Conflict tasks. Again, clearly, scores on the PANAS do not provide evidence of initial expectations compared to actual perceived experiences. This is something that could be investigated in a future study using the four stop-signal tasks, again employing the same method for assessing levels of reinforcement expectancies as used by Kambouropoulos and Staiger (2004; described above).

In conclusion, the results obtained in the present study have shown that inhibitory control and performance on the stop-signal task can be modified using different response contingencies and that these modifications were related to individual differences in reward and punishment sensitivity (i.e., personality). Further research is required in order to investigate some of the discrepancies observed concerning expected relationships between personality measures and response inhibition on the four tasks. The present study was limited by the fact that levels of reinforcement expectancies in relation to the tasks were not assessed and so it was not clear for whom manipulations of motivation (rewarding and punishing) were actually effective. Had these expectancies been assessed, more theoretically consistent relationships between personality and inhibitory control might have been obtained. However, this issue aside, the idea that performance on the stop-signal task can be modified using rewarding/punishing stimuli could provide valuable information on how to moderate and explain inhibitory control in other situations, such as gambling behaviour, in which disinhibitory behaviour leads to deleterious outcomes. In fact, higher SOGS score (used in the present study, out of interest, as a measure gambling severity among participants) was found to be associated with weaker inhibitory control on each of the four stop-signal tasks. No previous research has investigated pathological gamblers' inhibitory control on the standard stop-signal task, let alone across tasks with different response contingencies, compared to normal controls. This is the subject of chapter 6. The next chapter looks at personality in relation to performance on two tasks designed to measure gambling related inhibitory control.

# Chapter 5

# Experimental Study 4 (Part 2):

# Gambling Related Inhibitory Control and Personality on the Card Perseveration (CP) Task and Slot Machine Simulations

## 5.1 Aims and experimental predictions

### *5.1.1 Aims*

This study investigated inhibitory control on two types of gambling related computerised behavioural tasks, namely, the card perseveration (CP) task and the slot machine simulation, and its association with personality. More specifically, the aim was to investigate response perseveration on the CP task and the influence of a forced pause between response feedback and the opportunity to make another response, the influence of percentage payback (i.e., overall rate of reinforcement) on gambling behaviour on a computerised slot machine simulation, and the association of personality.

Toward this end, the two CP tasks described in detail in chapter 2, section 2.1.3, were used to assess response perseveration on both a 'Standard' and a 'Pause' version of the task. The two slot machine simulations described in chapter 2, section 2.1.4, were used to assess gambling behaviour on both a slot machine with a high percentage payback rate (70%) and a slot machine with a low percentage payback rate (30%). The same seven personality measures employed in chapter 4 (BIS/BAS Scales, SPSRQ, STAI Y2 scale, EPQ-RS, FSS, PANAS, and SOGS) were used for the same purposes as detailed in section 4.1.1. No previous research has investigated the influence of a forced pause alone on response perseveration on the CP task or the influence of these two percentage payback rates on gambling behaviour using a computerised slot machine simulation, within-subjects, and the association of personality.

### 5.1.2 Experimental predictions

A number of predictions were generated concerning the two CP tasks. First, the 5-s forced pause imposed following response feedback on the 'Pause' task should result in greater attention to response feedback on each trial and thus an earlier awareness of the decreasing rate of reward and increasing rate of punishment. This would prompt the prediction that an increased awareness of the changing task contingencies should result in lesser response perseveration (i.e., stronger inhibitory control) on the CP task with forced pause than on the standard task. Second, since previous research has demonstrated that normal control groups slow down after drawing a losing card compared to after drawing a winning card (Goudriaan et al., 2005), it was predicted that this same effect should be observed on the standard task in the present study.

In terms of the association of personality with performance on the two CP tasks, based on Arousal theory and Reinforcement Sensitivity Theory (RST), it was predicted that higher self-reported BAS activity (i.e., scores on the Sensitivity to Reward scale of the SPSRQ, and the BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales) and Extraversion (E) should be associated with greater response perseveration on both tasks and that, due to the presence of the 5-s forced pause following response feedback, these associations should be weaker on the CP task with forced pause than on the standard task. Conversely, higher self-reported BIS activity (i.e., scores on the BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, and the STAI), Fear (FSS score), and Neuroticism (N) should be associated with lesser response perseveration on both tasks and that, due to the presence of the 5-s forced pause following response feedback, these associations should be stronger on the CP task with forced pause than on the standard task. It was also predicted that higher self-reported BAS activity and Extraversion (E) should be associated with faster response latency following losses and that, in contrast, higher self-reported BIS activity, Fear, and Neuroticism (N) should be associated with slower response latency following losses.

A number of predictions were generated concerning the two slot machine simulations. First, exposure to the high rate of punishment on the simulation with low percentage payback rate should result in more cautious gambling behaviour in an attempt to minimise overall loss. This would prompt the prediction that an increased attempt to minimise overall loss should result in a lower total number of credits bet on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. Second, based on the findings of previous research (Dixon & Schreiber, 2002, 2004; Schreiber & Dixon, 2001), it was predicted that response latency should be faster following losing trials than following winning trials on both slot machine simulations. This, in turn, prompted the prediction that overall response latency should be fastest on the simulation with low percentage payback rate since it comprises a greater number of losing trials than the simulation with high percentage payback rate.

In terms of the association of personality with performance on the two slot machine simulations, based on Arousal theory and Reinforcement Sensitivity Theory (RST), it was predicted that higher self-reported BAS activity and Extraversion (E) should be associated with a higher total number of credits bet (i.e., more risky gambling behaviour; weaker inhibitory control) on both slot machine simulations and that, due to the lower overall rate of positive reinforcement, these associations should be weaker on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. Conversely, higher self-reported BIS activity, Fear, and Neuroticism (N) should be associated with a lower total number of credits bet (i.e., less risky gambling behaviour; stronger inhibitory control) on both slot machine simulations and that, due to the higher overall level of negative reinforcement, these associations should be stronger on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. It was also predicted that higher self-reported BAS activity and Extraversion (E) should be associated with faster response latency following losses and that, in contrast, higher self-reported BIS activity, Fear, and Neuroticism (N) should be associated with slower response latency following losses.

## 5.2 Method

### *5.2.1 Participants*

Participants were the same as those described in chapter 4, section 4.2.1.

### *5.2.2 Materials*

#### *5.2.2.1 Personality measures*

The personality measures are detailed, along with descriptive statistics including means, standard deviations, and correlations between personality measures, in chapter 4, section 4.2.2.1.

#### *5.2.2.2 Behavioural tasks*

The two card perseveration (CP) tasks (Standard and Pause) and the two slot machine simulations (high percentage payback rate and low percentage payback rate) are described in detail in chapter 2, sections 2.1.3 and 2.1.4, respectively. The written instructions given to participants for each of these experimental tasks are shown in full in Appendices I, J, K, and L, respectively.

### *5.2.3 Design*

The design was identical to that detailed in chapter 4, section 4.2.3. The order of the two slot machine simulations was kept the same across all participants. The order of the standard CP task and the CP task with forced pause was counterbalanced across participants in an attempt to minimize any possible conditioned learning effects for these tasks. Half of the participants performed the standard CP task first and half of the participants performed the CP task with forced pause first. Each participant performed the slot machine simulation with a high percentage payback rate first followed by the slot machine simulation with a low percentage payback rate.

*5.2.4 Procedure*

The procedure is detailed in chapter 4, section 4.2.4. The order in which the two CP tasks were administered and the order in which the two slot machine simulations were administered is described in the design section above (section 5.2.3).

*5.2.5 Dependent measures and data analyses of behavioural task performance*

*5.2.5.1 Dependent measures of card perseveration (CP) task performance*

The two dependent measures associated with response perseveration on the CP task comprise: (1) the number of cards played; and (2) the amount of cash won on exiting the task. Two other dependent measures of interest were also yielded from CP task performance: (1) response latency following wins; and (2) response latency following losses. See chapter 2, section 2.1.3.3, for detailed descriptions of these four dependent measures and methods for assessing them for each participant on each task.

*5.2.5.2 Dependent measures of slot machine simulation performance*

There were four dependent measures of interest yielded from slot machine simulation performance: (1) total credits bet; (2) response latency between "pulls"; (3) response latency following winning "pulls"; and (4) response latency following losing "pulls". See chapter 2, section 2.1.4.3, for detailed descriptions of these four dependent measures and methods for assessing them for each participant on each slot machine simulation.

*5.2.5.3 Data analyses of card perseveration (CP) task performance*

*5.2.5.3.1 Confirmatory analyses*

*5.2.5.3.1.1 Task effects on response perseveration*

Task effects on the two dependent measures of response perseveration (cards played and cash won) were analysed by mixed multivariate analysis of variance (MANOVA) with Task (Standard and Pause task) as the within-subjects factor treated multivariately. Sex (male or female) and Order (Standard task first or Pause task first) were included as between-subjects factors to assess the effects of gender and the counterbalancing variable Order on the two dependent measures across Task. Follow-up repeated measure ANOVAs generated by the overall mixed MANOVA were used to analyse each individual measure of response perseveration across Task.

*5.2.5.3.1.2 Effects of wins/losses on response latency*

Effects of the Outcome of the card drawn on mean response latency on the two tasks were analysed by separate three-way mixed analyses of variance (ANOVA) with Outcome (win and loss) as the within-subjects factor. Sex (male or female) and Order (Standard task first or Pause task first) were included as between-subjects factors to assess the effects of gender and the counterbalancing variable Order on mean response latency following wins/losses across Outcome.

*5.2.5.3.1.3 Personality*

In order to assess whether personality was associated with response perseveration and performance on the CP tasks, Pearson correlations were calculated between the four dependent measures of task performance (the two dependent measures of response perseveration: cards played and cash won; and the two dependent measures of response latency: mean response latency following wins and mean response latency following losses) for both tasks, on the one hand, and the personality measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, BIS, SP, SR, P, E, N, L, STAI, Fear, and SOGS score), on the other hand. Pearson correlations were also calculated between the four dependent measures of task performance for both tasks, on the one hand, and age, sex (with male coded as 1 and female coded as 2), and order (with Standard task first coded as 1 and Pause task first coded as 2), on the other hand, in order to investigate any associations between age, sex, order, and CP task performance.

*5.2.5.3.1.4 Task differences on associations between personality and response perseveration*

The combination of the categorical variable Task and the continuous variable Personality as predictors of the two dependent measures of response perseveration (cards played and cash won), was analysed by separate one-way repeated measure analyses of covariance (ANCOVA) with Task (Standard and Pause) as the within-subjects factor. Covariates were the subscales of the BIS/BAS Scales (BAS Drive, BAS Fun Seeking, BAS Reward Responsiveness, and BIS; in one ANCOVA), subscales of the SPSRQ (SP and SR; in one ANCOVA), subscales of the EPQ-RS (P, E, N, and L; in one ANCOVA), the STAI (in one ANCOVA), and FSS Fear (in one ANCOVA).

*5.2.5.3.2 Exploratory analyses*

*5.2.5.3.2.1 Task order and associations between personality and card perseveration (CP) task performance*

Associations between task performance measures and personality were analysed separately for the two groups that performed the CP tasks in different orders (Standard task first or Pause task first) in an attempt to investigate further and make sense of some of the unexpected findings revealed on and across tasks. Pearson correlations were calculated between the four dependent measures of performance (cards played, cash won, mean response latency following wins, and mean response latency following losses) for both tasks, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the four dependent measures of performance for both tasks, on the one hand, and age and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and performance.

*5.2.5.3.2.2 Sex and associations between personality and card perseveration (CP) task performance*

Associations between task performance measures and personality were analysed separately for sex (male and female) in an attempt to investigate further and make sense of some of the unexpected findings revealed on and across tasks. Pearson correlations were calculated between the four dependent measures of performance (cards played, cash won, mean response latency following wins, and mean response latency following losses) for both tasks, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the four dependent measures of performance for both tasks, on the one hand, and age, and order on the other hand, in order to investigate any associations between age, order, and task performance.

*5.2.5.4 Data analyses of slot machine simulation performance*

*5.2.5.4.1 Confirmatory analyses*

*5.2.5.4.1.1 Percentage payback rate effects*

Percentage payback rate effects on two dependent measures of slot machine simulation performance (total credits bet and mean response latency) were analysed by mixed multivariate analysis of variance (MANOVA) with Simulation (high percentage payback rate and low percentage payback rate) as the within-subjects factor treated multivariately. Sex (male or female) was included as the between-subjects factor to assess the effect of gender on these two dependent measures of performance across Simulation. Follow-up repeated measure ANOVAs generated by the overall mixed MANOVA were used to analyse each individual dependent measure across Simulation.

*5.2.5.4.1.2 Effects of wins/losses on response latency*

Effects of the Outcome of the stopped reels on mean response latency on the two simulations were analysed by separate two-way mixed analyses of variance (ANOVA) with Outcome (win and loss) as the within-subjects factor. Sex (male or female) was included as the between-subjects factor to assess the effects of gender on mean response latency following wins/losses across Outcome.

*5.2.5.4.1.3 Personality*

In order to assess whether personality was associated with slot machine simulation performance, Pearson correlations were calculated between the four dependent measures of performance (total credits bet, mean response latency, mean response latency following wins, and mean response latency following losses) for both simulations, on the one hand, and the personality measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, BIS, SP, SR, P, E, N, L, STAI, Fear, and SOGS score), on the other hand. Pearson correlations were also calculated between the four dependent measures of performance for both simulations, on the one hand, and age, and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and slot machine simulation performance.

*5.2.5.4.1.4 Simulation differences on associations between personality and total credits bet*

The combination of the categorical variable Simulation and the continuous variable Personality as predictors of total number of credits bet was analysed by separate one-way repeated measure analyses of covariance (ANCOVA) with Simulation (high percentage payback rate and low percentage payback rate) as the within-subjects factor. Covariates were the subscales of the BIS/BAS

Scales (BAS Drive, BAS Fun Seeking, BAS Reward Responsiveness, and BIS; in one ANCOVA), subscales of the SPSRQ (SP and SR; in one ANCOVA), subscales of the EPQ-RS (P, E, N, and L; in one ANCOVA), the STAI (in one ANCOVA), and FSS Fear (in one ANCOVA).

*5.2.5.4.2 Exploratory analyses*

*5.2.5.4.2.1 Personality and affect following stop-signal task performance*

Self-reported positive and negative affect scores, measured on the PANAS following performance of each of the two simulations, were investigated in an attempt to make sense of some of the unexpected findings revealed on and across the simulations. Associations between personality and positive and negative affect following performance of the two simulations were investigated using Pearson correlations, calculated between the two dependent measures of affect (positive and negative) following both simulations, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the two dependent measures of affect following both simulations, on the one hand, and age and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between age, sex, and affect following simulation performance.

*5.2.5.4.2.2 Sex and associations between personality and slot machine simulation performance*

Associations between slot machine simulation performance measures and personality were analysed separately for sex (male and female) in an attempt to investigate further and make sense of some of the unexpected findings revealed on and across the simulations. Pearson correlations were calculated between the four dependent measures of performance (total credits bet, mean response latency, mean response latency following wins, and mean response latency following losses) for both simulations, on the one hand, and the personality measures, on the other hand. Pearson correlations were also calculated between the four dependent measures of performance for both simulations, on the one hand, and age, on the other hand, in order to investigate any associations between age and simulation performance.

*5.2.5.5 Exploratory analyses*

Pearson correlations were calculated between the two dependent measures of response perseveration (number of cards played and amount of cash won) on the two CP tasks, total credits bet on both slot machine simulations, the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) on all four stop-signal tasks and Q-inhibition (the same participants performed the four stop-signal tasks and the Q-task, presented in chapter 4) to investigate associations between inhibition measures on and between experimental tasks.

## 5.3 Results

*5.3.1 Card perseveration (CP) tasks*

There were no univariate or multivariate outliers at $p < .001$ based on measures of response perseveration (cards played and cash won). $N = 21$ for both Sexes and both Orders. However, for analyses involving mean response latency (following wins and losses) on each of the tasks, some participants (five on the Standard task and two on the Pause task) exited very early in play and, as a result, were outliers due to a small number of reaction times after losses. The outliers were deleted for analyses involving mean response latency following wins and losses only, leaving 37 cases for analysis on the Standard task (18 males, 19 females; 19 in the group that performed the Standard task first, 18 in the group that performed the Pause task first) and 40 cases for analysis on the Pause task (19 males, 21 females; 20 in the group that performed the Standard task first, 20 in the group that performed the Pause task first). Means and standard deviations of CP task performance measures across the two tasks are shown in Table 5.1. Pause task mean response latencies shown in Table 5.1 are presented minus the 5-s forced pause.

Table 5.1

*Mean and Standard Deviation of Card Perseveration (CP) Task Performance Measures across the Two Tasks*

| Measure | CP Task | | | |
|---|---|---|---|---|
| | Standard | | Pause | |
| | Mean | SD | Mean | SD |
| No. of cards played[a] | 65.81 | 27.01 | 39.62 | 18.90 |
| Cash won ($)[a] | 185 | 99.71 | 258 | 45.72 |
| Mean response latency following wins (sec) | $1.81_b$ | $0.40_b$ | $1.03_c$ | $0.51_c$ |
| Mean response latency following losses (sec) | $1.69_b$ | $0.37_b$ | $0.86_c$ | $0.50_c$ |

*Note.* No. of cards played = number of cards played before exiting the game; Cash won ($) = amount of 'cash' won on exiting the game; mean response latency following wins = mean response latency between a winning card being drawn and the next card played in seconds; Mean response latency following losses = mean response latency between a losing card being drawn and the next card played in seconds.

[a]n = 42. [b]n = 37. [c]n = 40.

*5.3.1.1 Task effects on response perseveration*

Mixed MANOVA revealed significant multivariate effects for the main effect of Task on the two dependent measures of response perseveration, $F(2, 37) = 20.83, p < .01$; Wilks' Lambda = .47. Follow-up ANOVAs revealed that the two Tasks differed both in terms of number of cards played, $F(1, 38) = 42.75, p < .01$, and amount of cash won, $F(1, 38) = 19.32, p < .01$. Examination of means in Table 5.1 indicates that, consistent with prediction, a lower number of cards were played and a greater amount of cash was won (i.e., response perseveration was lesser) on the Pause task (39.62 and $258, respectively) than on the Standard task (65.81 and $185, respectively). There was no significant main effect of Sex, $F(2, 37) = 0.73, p > .05$; Wilks' Lambda = .96, no significant main effect of Order, $F(2, 37) = 1.86, p > .05$; Wilks' Lambda = .91, no significant interaction between

Sex and Task, $F(2, 37) = 0.25, p > .05$; Wilks' Lambda = .99, and no significant interaction between Order and Task, $F(2, 37) = 0.22, p > .05$; Wilks' Lambda = .99.

*5.3.1.2 Effects of wins/losses on response latency*

*5.3.1.2.1 Standard task*

ANOVA revealed a significant main effect of Outcome, $F(1, 33) = 7.78, p < .01$. Examination of means in Table 5.1 indicates that, contrary to prediction, mean response latency was faster following losses (1.69-sec) than following wins (1.81-sec). There was no significant main effect of Sex, $F(1, 33) = 1.49, p > .05$, no significant interaction between Sex and Outcome, $F(1, 33) = 0.05$, $p > .05$, and no significant interaction between Order and Outcome, $F(1, 33) = 0.99, p > .05$. However, there was a significant main effect of Order, $F(1, 33) = 11.08, p < .01$. Mean response latency across the two orders is shown in Figure 5.1. Examination of Figure 5.1 indicates that mean response latency following both outcomes (wins and losses) on the Standard task was faster for the group that performed the Pause task first than for the group that performed the Standard task first.

*5.3.1.2.2 Pause task*

ANOVA revealed a significant main effect of Outcome, $F(1, 36) = 7.56, p < .01$. Examination of means in Table 5.1 indicates that mean response latency was faster following losses (0.86-sec) than following wins (1.03-sec). There was no significant main effect of Sex, $F(1, 36) = 0.03, p > .05$, no significant main effect of Order, $F(1, 36) = 0.96, p > .05$, no significant interaction between Sex and Outcome, $F(1, 36) = 0.05, p > .05$, and no significant interaction between Order and Outcome, $F(1, 36) = 2.56, p > .05$.

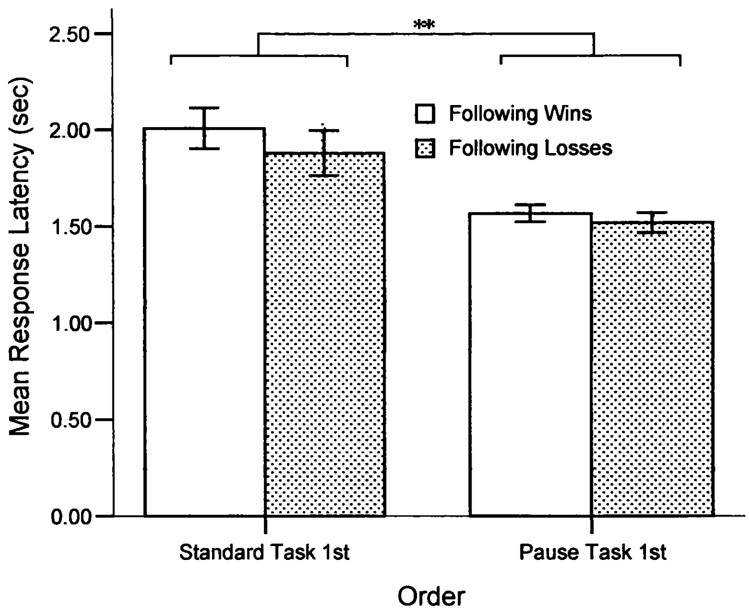


*Figure 5.1.* Mean response latency ( ± 1 SE) following wins and losses on Standard card perseveration (CP) task for group that performed the Standard task first (n = 19) and group that performed the Pause task first (n = 18).

$^{**}p < .01$.

### *5.3.1.3 Personality and card perseveration (CP) task performance*

Preliminary analyses revealed one case with an extremely high z score (beyond the $p = .001$ criterion of 3.29, two-tailed) on EPQ-RS Lie to be a univariate outlier. Since the Lie scale is designed for the revelation of dishonesty, the case with the extremely high Lie scale score was deleted from all analyses involving self-reported personality measures. Table 5.2 shows correlations between the dependent measures of CP task performance on the two tasks and personality measures, age, sex, and order. Due to the presence of significant correlations between the EPQ-RS Lie scale and cards played on the Pause task, $r(41) = .41, p < .01$, between age and cash won on the Standard task, $r(41) = -.37$, $p < .05$, and between order and mean response latency following wins, $r(36) = -.48, p < .01$, and following losses, $r(36) = -.42, p < .05$, on the Standard task, Table 5.2 also shows partial correlations, controlling for Lie scale score, age, and order, between the dependent measures of CP task performance on the two tasks and personality measures and sex.

Table 5.2

*Correlations between Card Perseveration (CP) Task Performance Measures on the Two Tasks and Personality Measures, Age, Sex, and Order*

| Task | Measure | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex | Order |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Cards[a] | .15 | .25 | .31* | .37* | .17 | .09 | -.02 | -.01 | .22 | .13 | .09 | -.01 | .05 | .11 | .03 | .14 |
| | Cash[a] | -.10 | -.19 | -.14 | -.27 | -.13 | -.05 | .04 | .13 | -.01 | -.18 | -.01 | -.12 | -.21 | -.37* | .07 | -.19 |
| | MRL-w[b] | -.32 | -.17 | -.02 | -.04 | .20 | .19 | .16 | .16 | .12 | -.25 | -.01 | .18 | -.08 | .15 | .14 | -.48** |
| | MRL-l[b] | -.29 | -.15 | .03 | -.08 | .22 | .12 | .10 | .10 | .14 | -.06 | -.08 | .14 | -.03 | .06 | .18 | -.42* |
| Pause | Cards[a] | .07 | -.07 | .13 | .17 | .11 | -.15 | -.24 | -.01 | .18 | .41** | .16 | -.07 | -.20 | -.18 | .01 | .26 |
| | Cash[a] | -.26 | .12 | .16 | .23 | .15 | .00 | -.17 | .14 | .31* | -.31 | .24 | .07 | .01 | .12 | .30 | -.27 |
| | MRL-w[c] | -.23 | -.31 | .02 | .06 | .04 | -.03 | -.20 | -.30 | -.06 | .04 | -.01 | .00 | .38* | .13 | -.05 | -.04 |
| | MRL-l[c] | -.39* | -.50** | -.08 | .20 | .33* | -.01 | .07 | -.40* | .14 | -.08 | .28 | .20 | .32* | .27 | -.02 | -.24 |
| Standard[d] | Cards[a] | .13 | .26 | .30 | .41* | .23 | .14 | -.01 | .02 | .28 | — | .13 | .05 | .08 | — | .05 | — |
| | Cash[a] | -.09 | -.18 | -.06 | -.38* | -.28 | -.08 | .08 | .11 | -.12 | — | -.06 | -.24 | -.24 | — | .04 | — |
| | MRL-w[b] | -.30 | -.28 | -.07 | -.01 | .22 | .07 | .02 | .04 | .10 | — | -.05 | .12 | -.28 | — | .16 | — |
| | MRL-l[b] | -.29 | -.18 | .01 | -.10 | .24 | .11 | -.01 | .01 | .15 | — | -.11 | .11 | -.14 | — | .21 | — |
| Pause[d] | Cards[a] | -.02 | .00 | .19 | .16 | .18 | .07 | -.12 | .11 | .31 | — | .27 | .05 | -.09 | — | .05 | — |
| | Cash[a] | -.21 | .09 | .16 | .27 | .12 | -.18 | -.33 | .06 | .27 | — | .19 | -.03 | -.11 | — | .30 | — |
| | MRL-w[c] | -.23 | -.32 | -.01 | .07 | .06 | -.04 | -.26 | -.31 | -.05 | — | -.01 | .00 | .37* | — | -.04 | — |
| | MRL-l[c] | -.37* | -.56** | -.15 | .23 | .36* | -.11 | -.07 | -.48** | .14 | — | .27 | .17 | .24 | — | -.01 | — |

*Note.* Cards = number of cards played before exiting the game; Cash = amount of 'cash' ($) won on exiting the game; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]n = 41. [b]n = 36. [c]n = 39. [d]Partial correlations controlling for the following variables: Lie scale score, age, and order.

*$p < .05$. **$p < .01$.

*5.3.1.3.1 Response perseveration*

Partial correlations shown in Table 5.2 revealed, as expected, significant correlations for measures of response perseveration (cards played and cash won) on the Standard CP task and a measure of BIS activity. However, contrary to prediction, a higher score on the BIS scale was related to a higher number of cards played, $r(36) = .41, p < .05$, and a smaller amount of cash won, $r(36) = -.38, p < .05$, (i.e., greater response perseveration) on the Standard task. Also contrary to prediction, a higher score on the Sensitivity to Punishment scale (BIS measure) was near significantly related to a smaller amount of cash won on the Standard task, , $r(36) = -.28, p = .09$. This finding was not, however, supported by a significant correlation between the other measure of response perseveration, number of cards played, on the Standard task and Sensitivity to Punishment scale score, $p > .05$. Contrary to prediction, no measure of BIS activity (BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, STAI trait anxiety) was significantly related to the two measures of response perseveration on the Pause task, $p > .05$.

Consistent with prediction, a higher score on a measure of BAS activity, the BAS Reward Responsiveness scale, was near significantly related to a higher number of cards played (i.e., greater response perseveration) on the Standard task, $r(36) = .30, p = .07$. This finding was not, however, supported by a significant correlation between the other measure of response perseveration, amount of cash won, on the Standard task and BAS Reward Responsiveness score, $p > .05$. Contrary to prediction, no other measure of BAS activity (Sensitivity to Reward scale of the SPSRQ, BAS Drive, and BAS Fun Seeking scales of the BIS/BAS Scales) was significantly related to the two measures of response perseveration on the Standard task, $p > .05$, and no measure of BAS activity was significantly related to the two measures of response perseveration on the Pause task, $p > .05$.

Examination of partial correlations in Table 5.2 shows that, contrary to prediction, a higher score on the Neuroticism scale was near significantly related to a higher number of cards played both on the Standard task, $r(36) = .28, p = .09$, and on the Pause task, $r(36) = .31, p = .06$. However, Neuroticism score was not significantly related to the other measure of response perseveration, amount of cash won, on the Standard task and a higher score on the Neuroticism scale was actually near significantly related to a greater amount of cash won (i.e., lesser response perseveration) on the Pause task, $r(36) = .27, p = .10$, consistent with prediction.

Contrary to prediction, the Extraversion scale of the EPQ-RS was not significantly related to the two measures of response perseveration on either of the two tasks, $p > .05$, and neither was FSS Fear, $p > .05$.

*5.3.1.3.2 Response latency*

Examination of partial correlations in Table 5.2 shows that, consistent with prediction, a higher score on a measure of BAS activity, the BAS Drive scale, was near significantly related to a faster mean response latency following losses on the Standard task, $r(31) = -.29, p = .10$. No other measure of BAS activity (Sensitivity to Reward scale of the SPSRQ, BAS Fun Seeking and BAS Reward Responsiveness scales of the BIS/BAS Scales) was significantly related to mean response latency following losses on the Standard task, $p > .05$, contrary to prediction. A higher score on the BAS Drive scale was, however, near significantly related to a faster mean response latency following wins on the Standard task, $r(31) = -.30, p = .09$, and was significantly related to a faster mean response latency following losses on the Pause task, $r(34) = -.37, p < .05$. A higher score on another measure of BAS activity, the BAS Fun Seeking scale, was also significantly related to a faster mean response latency following losses on the Pause task, $r(34) = -.56, p < .01$, and was near significantly related to a faster mean response latency following wins on this same task, $r(34) = -.32, p = .06$.

Contrary to prediction, partial correlations shown in Table 5.2 revealed that no measure of BIS activity (BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, STAI trait anxiety) was significantly related to mean response latency following losses on the Standard task,

$p > .05$, and neither was FSS Fear, $p > .05$. However, a higher score on the Sensitivity to Punishment scale (BIS measure) was significantly related to a slower mean response latency following losses on the Pause task, $r(34) = .36, p < .05$.

The Extraversion and Neuroticism scales of the EPQ-RS were not significantly related to mean response latency following losses on the Standard task, $p > .05$, contrary to prediction. A higher score on the Extraversion scale was, however, significantly related to a faster mean response latency following losses on the Pause task, $r(34) = -.48, p < .01$, and near significantly related to a faster mean response latency following wins on this same task, $r(34) = -.31, p = .06$. A higher score on the SOGS was significantly related to a slower mean response latency following wins on the Pause task, $r(34) = .37, p < .05$.

*5.3.1.4 Task differences on associations between personality and response perseveration*

*5.3.1.4.1 BIS/BAS Scales*

ANCOVA revealed a significant interaction between Task and BAS Fun Seeking, $F(1, 36) = 4.84$, $p < .05$. This suggests that, as expected, the response of number of cards played to BAS (as measured by this scale) differed according to Task. Figure 5.2 displays the correlation between cards played and BAS Fun Seeking on both tasks. The regression lines in the left and right panels (Standard task and Pause task, respectively) of Figure 5.2 indicate that, in general, consistent with prediction, a higher score on the BAS Fun Seeking scale was more strongly associated with a higher number of cards played (i.e., greater response perseveration) on the Standard task than on the Pause task.

There was a near significant interaction between Task and BIS, $F(1, 36) = 3.93, p = .06$, for cards played. This suggests that, as expected, the response of number of cards played to BIS differed according to Task. Figure 5.3 displays the correlation between cards played and BIS on both tasks. The regression lines in the left and right panels (Standard task and Pause task, respectively) of Figure

5.3 indicate that, contrary to prediction, a higher score on the BIS scale was related to a higher number of cards played on the Standard task, $p < .05$, and, in general, there was a slight trend toward this same association on the Pause task although not as strong as on the Standard task.

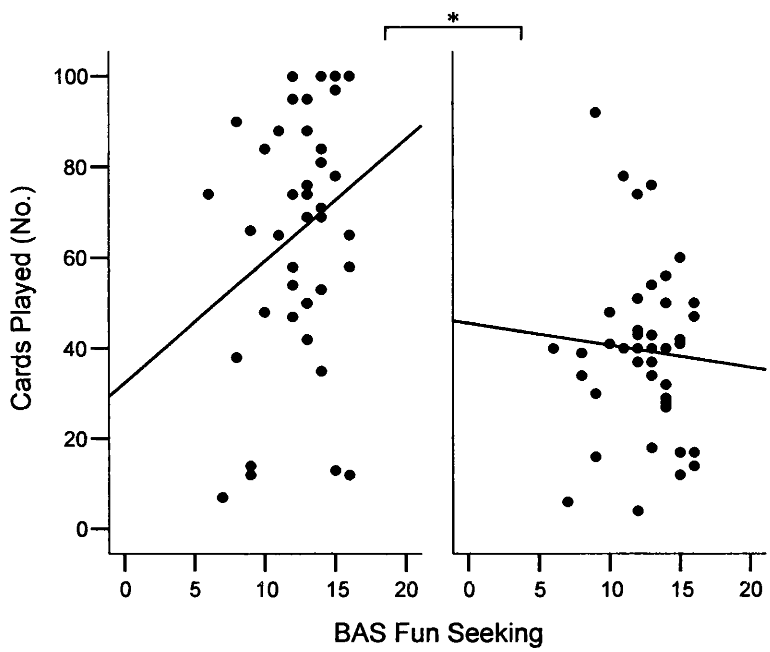


*Figure 5.2.* BAS Fun Seeking scores and number of cards played before exiting (with regression line) for Standard (left panel) and Pause (right panel) card perseveration (CP) tasks.

*$p < .05$.

There was no significant interaction between Task and BAS Drive, $F(1, 36) = 0.10, p > .05$, or between Task and BAS Reward Responsiveness, $F(1, 36) = 0.23, p > .05$, for cards played, contrary to prediction. For the other dependent measure of response perseveration, amount of cash won, ANCOVA revealed a significant interaction between Task and BAS Fun Seeking, $F(1, 36) = 4.78$, $p < .05$. This suggests that, as expected, the response of cash won to BAS (as measured by this scale) differed according to Task. Figure 5.4 displays the correlation between cash won and BAS Fun Seeking on both tasks. The regression lines in the left and right panels (Standard task and Pause task, respectively) of Figure 5.4 indicate that, consistent with prediction, a higher score on the BAS Fun

Seeking scale was more strongly associated with a smaller amount of cash won (i.e., greater response perseveration) on the Standard task than on the Pause task.

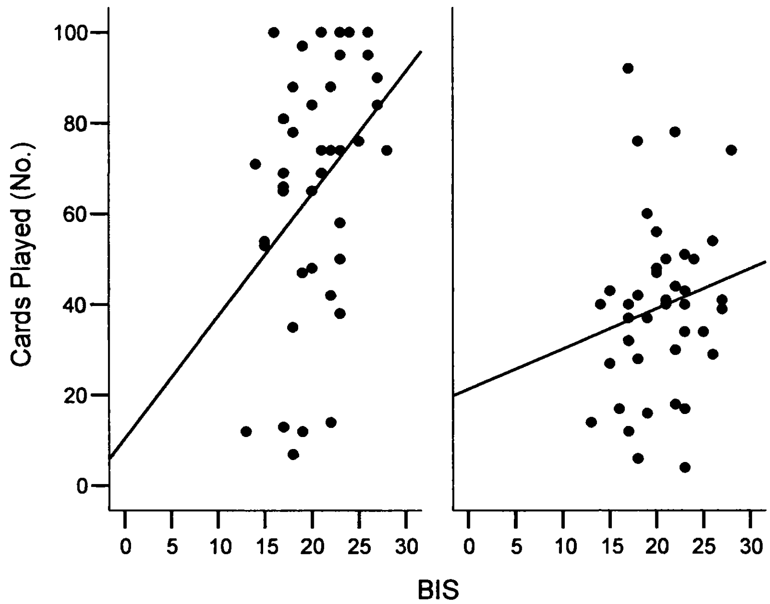


*Figure 5.3.* BIS scores and number of cards played before exiting (with regression line) for Standard (left panel) and Pause (right panel) card perseveration (CP) tasks.

There was a significant interaction between Task and BIS, $F(1, 36) = 5.52, p < .05$, for amount of cash won. This suggests that, as expected, the response of cash won to BIS differed according to Task. Figure 5.5 displays the correlation between cash won and BIS on both tasks. The regression lines in the left and right panels (Standard task and Pause task, respectively) of Figure 5.5 indicate that although, in general, contrary to prediction, there was a moderate trend toward a higher score on the BIS scale being associated with a smaller amount of cash won on the Standard task, there was a slight trend toward the opposite, predicted, association on the Pause task. There was no significant interaction between Task and BAS Drive, $F(1, 36) = 0.96, p > .05$, or between Task and BAS Reward Responsiveness, $F(1, 36) = 0.33, p > .05$, for amount of cash won, contrary to prediction.

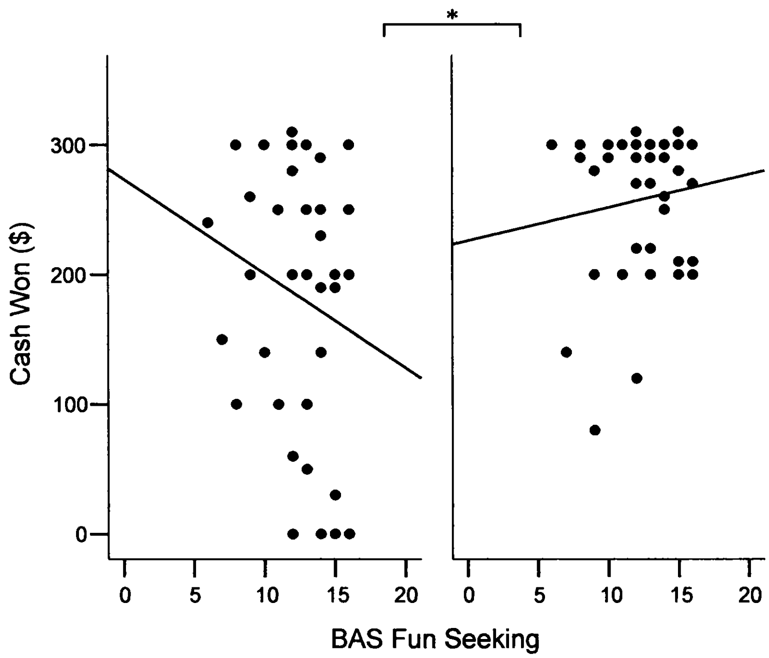


*Figure 5.4.* BAS Fun Seeking scores and amount of 'cash' won on exiting (with regression line) for Standard (left panel) and Pause (right panel) card perseveration (CP) tasks.

*$p < .05$.

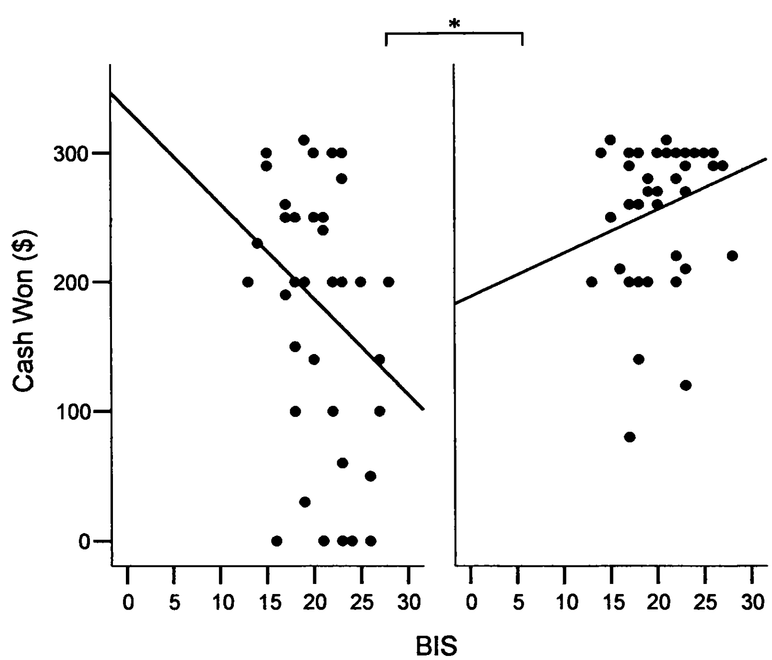


*Figure 5.5.* BIS scores and amount of 'cash' won on exiting (with regression line) for Standard (left panel) and Pause (right panel) card perseveration (CP) tasks.

*$p < .05$.

*5.3.1.4.2 Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ)*

ANCOVA revealed no significant interaction between Task and Sensitivity to Punishment, $F(1, 38) = 0.33, p > .05$, and no significant interaction between Task and Sensitivity to Reward, $F(1, 38) = 1.60, p > .05$, for cards played, contrary to prediction.

For the other dependent measure of response perseveration, amount of cash won, ANCOVA again revealed no significant interaction between Task and Sensitivity to Punishment, $F(1, 38) = 1.55$, $p > .05$, and no significant interaction between Task and Sensitivity to Reward, $F(1, 38) = 0.04$, $p > .05$, contrary to prediction.

*5.3.1.4.3 Revised Eysenck Personality Questionnaire short scale (EPQ-RS)*

ANCOVA revealed no significant interaction between Task and Extraversion, $F(1, 36) = 0.00$, $p > .05$, and no significant interaction between Task and Neuroticism, $F(1, 36) = 0.33, p > .05$, for cards played, contrary to prediction. There was no significant interaction between Task and Psychoticism, $F(1, 36) = 0.85, p > .05$, and no significant interaction between Task and Lie, $F(1, 36) = 0.57, p > .05$.

For the other dependent measure of response perseveration, amount of cash won, ANCOVA again revealed no significant interaction between Task and Extraversion, $F(1, 36) = 0.01, p > .05$, and no significant interaction between Task and Neuroticism, $F(1, 36) = 0.75, p > .05$, contrary to prediction. There was no significant interaction between Task and Psychoticism, $F(1, 36) = 0.23$, $p > .05$, and no significant interaction between Task and Lie, $F(1, 36) = 0.03, p > .05$.

*5.3.1.4.4 Spielberger State-Trait Anxiety Inventory (STAI)*

ANCOVA revealed no significant interaction between Task and STAI, $F(1, 39) = 0.01, p > .05$, for cards played, contrary to prediction. For the other dependent measure of response perseveration, amount of cash won, ANCOVA again revealed no significant interaction between Task and STAI, $F(1, 39) = 0.62, p > .05$, contrary to prediction.

*5.3.1.4.5 Fear Survey Schedule (FSS)*

ANCOVA revealed no significant interaction between Task and Fear, $F(1, 39) = 0.08, p > .05$, for cards played, contrary to prediction. For the other dependent measure of response perseveration, amount of cash won, ANCOVA again revealed no significant interaction between Task and Fear, $F(1, 39) = 0.89, p > .05$, contrary to prediction.

*5.3.1.4 Task order and associations between personality and card perseveration (CP) task performance*

Table 5.3 shows correlations between the dependent measures of CP task performance on the two tasks and personality measures, age, and sex for the two groups that performed the tasks in different orders. Due to the presence of significant correlations between the EPQ-RS Lie scale and cards played on the Pause task for the group that performed this task first, $r(20) = .50, p < .05$, between age and cash won on the Standard task for the group that performed the Standard task first, $r(21) = -.50$, $p < .05$, and between sex and mean response latency following losses on the Standard task, $r(17) = .48, p < .05$, and cash won on the Pause task, $r(20) = .52, p < .05$, for the group that performed the Pause task first, partial correlations, controlling for Lie scale score, age, and sex, between the dependent measures of CP task performance on the two tasks and personality measures for the two groups that performed the tasks in different orders are shown in Table 5.4.

Table 5.3

*Correlations between Card Perseveration (CP) Task Performance Measures on the Two Tasks and Personality Measures, Age, and Sex for the Two Groups that Performed the Tasks in Different Orders*

| Task | Measure | Order | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Cards | S 1st [a] | .39 | .50* | .56** | .29 | -.09 | .26 | .02 | .09 | .05 | .18 | .01 | -.21 | .09 | .16 | -.07 |
| | | P 1st [b] | -.14 | -.02 | .14 | .48* | .46* | -.04 | .01 | -.05 | .43 | .03 | .21 | .23 | .08 | .07 | .14 |
| | Cash | S 1st [a] | -.31 | -.16 | -.40 | -.31 | -.13 | -.25 | -.04 | .21 | .03 | -.27 | -.14 | -.05 | -.28 | -.50* | .12 |
| | | P 1st [b] | .19 | -.18 | .05 | -.29 | -.21 | .12 | .02 | .01 | -.11 | -.04 | .07 | -.29 | -.24 | -.27 | .01 |
| | MRL-w | S 1st [c] | -.39 | -.30 | -.24 | .03 | .41 | .15 | .24 | .03 | .17 | -.06 | -.01 | .34 | -.23 | -.01 | .10 |
| | | P 1st [d] | -.18 | -.03 | .27 | -.28 | -.26 | .27 | -.30 | .15 | -.02 | -.46 | -.13 | -.21 | -.15 | .47 | .32 |
| | MRL-l | S 1st [c] | -.33 | -.28 | -.01 | -.09 | .34 | .15 | .20 | -.09 | .19 | .16 | -.17 | .10 | -.16 | .12 | .08 |
| | | P 1st [d] | -.20 | .05 | .08 | -.15 | -.04 | .02 | -.36 | .21 | .02 | -.26 | -.04 | .10 | -.06 | -.05 | .48* |
| Pause | Cards | S 1st [a] | .10 | .22 | .23 | .32 | -.01 | .07 | -.15 | .03 | .38 | .18 | .18 | -.16 | -.44* | -.26 | -.19 |
| | | P 1st [b] | .00 | -.27 | .11 | .17 | .25 | -.23 | -.21 | .05 | .18 | .50* | .24 | .05 | -.02 | -.13 | .13 |
| | Cash | S 1st [a] | -.12 | .13 | .26 | .45* | .18 | .03 | -.12 | -.13 | .47* | -.11 | .38 | .02 | -.31 | -.10 | -.02 |
| | | P 1st [b] | -.32 | .18 | .12 | .07 | .08 | -.04 | -.32 | .21 | .18 | -.37 | .10 | .02 | .12 | .24 | .52* |
| | MRL-w | S 1st [b] | -.42 | -.67** | -.08 | .31 | .19 | -.17 | -.25 | -.41 | .00 | .14 | .08 | .08 | .47* | .05 | -.02 |
| | | P 1st [c] | .02 | .10 | .09 | -.25 | -.16 | .12 | -.19 | -.21 | -.16 | -.07 | -.14 | -.12 | .26 | .22 | -.09 |
| | MRL-l | S 1st [b] | -.62** | -.72** | -.22 | .38 | .50* | -.13 | .01 | -.61* | .26 | -.10 | .43 | .35 | .30 | .37 | .05 |
| | | P 1st [c] | .23 | -.13 | .09 | -.28 | -.10 | .16 | -.03 | -.25 | -.24 | .13 | -.08 | -.26 | .34 | .03 | -.23 |

*Note.* S 1st = group that performed Standard task first; P 1st = group that performed Pause task first; Cards = number of cards played before exiting the game; Cash = amount of 'cash' ($) won on exiting the game; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a] n = 21. [b] n = 20. [c] n = 19. [d] n = 17.

*$p$ < .05. **$p$ < .01.

Table 5.4

*Partial Correlations[a] between Card Perseveration (CP) Task Performance Measures on the Two Tasks and Personality Measures for the Two Groups that Performed the Tasks in Different Orders*

| Task | Measure | Order | BD | BFS | BRR | BIS | SP | SR | P | E | N | STAI | Fear | SOGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Cards | S 1st [b] | .43 | .56* | .55* | .27 | -.04 | .33 | .02 | .17 | .09 | .06 | -.18 | .09 |
| | | P 1st [c] | -.13 | -.01 | .10 | .53* | .52* | .01 | .13 | -.08 | .48 | .24 | .21 | .07 |
| | Cash | S 1st [b] | -.48* | -.27 | -.34 | -.32 | -.24 | -.34 | .08 | .06 | -.03 | -.21 | -.13 | -.26 |
| | | P 1st [c] | .23 | -.16 | .13 | -.40 | -.32 | .20 | .05 | .09 | -.17 | .07 | -.36 | -.21 |
| | MRL-w | S 1st [d] | -.42 | -.33 | -.27 | .08 | .45 | .19 | .24 | -.02 | .21 | .02 | .33 | -.25 |
| | | P 1st [e] | -.14 | -.30 | .01 | -.18 | -.04 | .09 | -.20 | -.16 | .14 | .04 | -.42 | -.38 |
| | MRL-l | S 1st [d] | -.40 | -.31 | -.14 | -.10 | .48 | .25 | .21 | -.17 | .34 | -.06 | .14 | -.16 |
| | | P 1st [e] | -.13 | .04 | -.12 | -.14 | .04 | .05 | -.07 | .09 | .13 | .12 | -.09 | -.04 |
| Pause | Cards | S 1st [b] | .07 | .27 | .28 | .27 | .06 | .11 | .03 | .02 | .46 | .30 | -.05 | -.45 |
| | | P 1st [c] | -.03 | -.11 | .24 | .21 | .18 | .15 | -.16 | .21 | .26 | .21 | .04 | .07 |
| | Cash | S 1st [b] | -.13 | .12 | .35 | .50* | .16 | .00 | -.13 | -.16 | .47 | .41 | .00 | -.33 |
| | | P 1st [c] | -.26 | .18 | -.21 | .18 | .28 | -.24 | .00 | .05 | .36 | .36 | -.24 | .07 |
| | MRL-w | S 1st [c] | -.46 | -.66** | -.15 | .29 | .27 | -.16 | -.26 | -.48 | .05 | .16 | .14 | .51* |
| | | P 1st [d] | .00 | .02 | .06 | -.19 | -.09 | .03 | -.35 | -.32 | -.14 | -.14 | -.08 | .22 |
| | MRL-l | S 1st [c] | -.61** | -.76** | -.27 | .52* | .52* | -.23 | -.19 | -.65** | .31 | .46 | .31 | .23 |
| | | P 1st [d] | .18 | -.17 | .18 | -.28 | -.11 | .23 | -.25 | -.25 | -.26 | -.14 | -.18 | .36 |

*Note.* S 1st = group that performed Standard task first; P 1st = group that performed Pause task first; Cards = number of cards played before exiting the game; Cash = amount of 'cash' ($) won on exiting the game; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]The following variables were controlled for: Lie scale score, age, and sex. [b]n = 21. [c]n = 20. [d]n = 19. [e]n = 17.

*$p < .05$. **$p < .01$.

Examination of Table 5.4 shows that a higher BAS Fun Seeking score and a higher BAS Reward Responsiveness score were significantly related to a higher number of cards played (i.e., greater response perseveration) on the Standard task, $r(16) = .56$, $p < .05$, and, $r(16) = .55$, $p < .05$, respectively, consistent with prediction, but only for the group that performed the Standard task first. A higher score on another measure of BAS activity, the BAS Drive scale, was significantly related to a smaller amount of cash won (i.e., greater response perseveration), $r(16) = -.48$, $p < .05$, and near significantly related to a higher number of cards played, $r(16) = .43$, $p = .07$, on the Standard task, consistent with prediction, but again only for the group that performed this task first. These significant and near significant correlations between measures of BAS activity and measures of response perseveration were not present on the Pause task for either group, $p > .05$.

Examination of Table 5.4 also shows that a higher BIS score and a higher Sensitivity to Punishment (i.e., BIS) score were significantly related to a higher number of cards played (i.e., greater response perseveration) on the Standard task, $r(15) = .53$, $p < .05$, and, $r(15) = .52$, $p < .05$, respectively, contrary to prediction, but only for the group that performed the Pause task first. Also, a higher score on the Neuroticism scale was near significantly related to a higher number of cards played on the Standard task, $r(15) = .48$, $p = .05$, contrary to prediction, but again only for the group that performed the Pause task first. A higher BIS score was actually significantly related to a greater amount of cash won (i.e., lesser response perseveration) on the Pause task, $r(16) = .50$, $p < .05$, consistent with prediction, but only for the group that performed the Standard task first. Also, a higher Neuroticism score and a higher STAI (i.e., BIS) score were near significantly related to a greater amount of cash won on the Pause task, $r(16) = .47$, $p = .05$, and, $r(16) = .41$, $p = .09$, respectively, again consistent with prediction, but again only for the group that performed the Standard task first.

In terms of mean response latency (following wins and losses), examination of Table 5.4 shows that a higher BAS Drive score was near significantly related to a faster mean response latency following wins on the Standard task, $r(14) = -.42$, $p = .10$, but only for the group that performed this task first. In contrast, a higher Sensitivity to Punishment (i.e., BIS) score was near significantly related to a slower mean response latency following wins, $r(14) = .45$, $p = .08$, and, consistent with prediction, a slower mean response latency following losses, $r(14) = .48$, $p = .06$, on the Standard task, again only for the group that performed this task first.

A higher BAS Drive score, BAS Fun Seeking score and Extraversion score were significantly related to a faster mean response latency following losses on the Pause task, $r(15) = -.61$, $p < .01$, $r(15) = -.76$, $p < .01$, and, $r(15) = -.65$, $p < .01$, respectively, but only for the group that performed the Standard task first. A higher BAS Fun Seeking score was also significantly related to a faster mean response latency following wins on the Pause task for this same group only, $r(15) = -.66$, $p < .01$, and a higher BAS Drive score and a higher Extraversion score were near significantly related to a faster mean response latency following wins on this same task, $r(15) = -.46$, $p = .07$, and, $r(15) = -.48$, $p = .05$, respectively, again only for the group that performed the Standard task first. In contrast, a higher BIS score and a higher Sensitivity to Punishment (i.e., BIS) score were significantly related to a slower mean response latency following losses on the Pause task, $r(15) = .52$, $p < .05$, and, $r(15) = .52$, $p < .05$, respectively, only for the group that performed the Standard task first. Also, a higher STAI (i.e., BIS) score was near significantly related to a slower mean response latency following losses on this task again only for the group that performed the Standard task first, $r(15) = .46$, $p = .06$.

*5.3.1.5 Sex and associations between personality and card perseveration (CP) task performance*

Table 5.5 shows correlations between the dependent measures of CP task performance on the two tasks and personality measures, age, and order for both males and females. Due to the presence of significant correlations between the EPQ-RS Lie scale and cards played, $r(20) = .59$, $p < .01$, and between order and cash won, $r(20) = -.48$, $p < .05$, on the Pause task for the male group, between age and cash won, $r(20) = -.56$, $p < .05$, order and mean response latency following wins, $r(17) = -.56$, $p < .05$, and between order and mean response latency following losses, $r(17) = -.51$, $p < .05$, on the Standard task for the male group, and between order and cards played on the Pause task for the female group, $r(21) = .53, p < .05$, partial correlations, controlling for Lie scale score, age, and order, between the dependent measures of CP task performance on the two tasks and personality measures for both males and females are shown in Table 5.6.

Examination of Table 5.6 shows that, consistent with prediction, a higher BAS Drive score, BAS Fun Seeking score, BAS Reward Responsiveness score and Extraversion score were significantly related to a higher number of cards played (i.e., greater response perseveration) on the Standard task, $r(16) = .48, p < .05$, $r(16) = .64, p < .01$, $r(16) = .60, p < .01$, and, $r(16) = .50, p < .05$, respectively, and a higher BAS Fun Seeking score was near significantly related to a smaller amount of cash won (i.e., greater response perseveration) on this same task, $r(16) = -.47, p = .05$. However, these significant (and near significant) correlations were obtained for the female group only. These significant and near significant correlations between measures of BAS activity, Extraversion, and measures of response perseveration were not present on the Pause task for either group, $p > .05$.

Contrary to prediction, a higher BIS score, Sensitivity to Punishment (i.e., BIS) score, STAI (i.e., BIS) score and Neuroticism score were significantly related to a higher number of cards played on the Standard task, $r(15) = .71, p < .01$, $r(15) = .54, p < .05$, $r(15) = .55, p < .05$, and, $r(15) = .65$, $p < .05$, respectively, and a higher Sensitivity to Punishment score and a higher Fear score were significantly related to a smaller amount of cash won on this same task, $r(15) = -.53, p < .05$, and, $r(15) = -.56, p < .05$, respectively. Also contrary to prediction, a higher BIS score was near significantly related to a smaller amount of cash won on the Standard task, $r(15) = -.42, p < .10$. However, these significant (and near significant) correlations were obtained for the male group only. On the Pause task, for the male group, a higher STAI (i.e., BIS) score and a higher Neuroticism score were significantly related to a greater amount of cash won, $r(15) = .57, p < .05$, and, $r(15) = .57$, $p < .05$, respectively, consistent with prediction. Contrary to prediction, however, for the female group on the Pause task, a higher BIS score was significantly related to a higher number of cards played, $r(16) = .49, p < .05$.

Table 5.5

*Correlations between Card Perseveration (CP) Task Performance Measures on the Two Tasks and Personality Measures, Age, and Order for Both Sexes*

| Task | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Order |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Cards | M[a] | -.22 | -.05 | .14 | .67** | .41 | -.02 | -.01 | -.34 | .49* | .19 | .42 | .10 | .26 | .36 | .03 |
| | | F[b] | .42 | .59** | .56** | .08 | -.13 | .28 | -.01 | .36 | -.16 | .06 | -.24 | -.10 | -.20 | -.11 | .25 |
| | Cash | M[a] | .25 | .09 | .08 | -.36 | -.34 | .07 | .06 | .25 | -.06 | -.06 | -.15 | -.29 | -.46* | -.56* | -.14 |
| | | F[b] | -.32 | -.44* | -.46* | -.20 | .08 | -.14 | .05 | -.01 | .08 | -.31 | .15 | -.07 | .08 | -.22 | -.23 |
| | MRL-w | M[c] | -.18 | .13 | .05 | .16 | .00 | .11 | .16 | .29 | .04 | -.10 | -.04 | .08 | .11 | .31 | -.56* |
| | | F[d] | -.41 | -.43 | -.15 | -.13 | .40 | .40 | .22 | -.07 | .29 | -.38 | .10 | .19 | -.22 | .05 | -.43 |
| | MRL-l | M[c] | -.25 | -.06 | .04 | .26 | .11 | .00 | .02 | .02 | .19 | .18 | -.10 | -.09 | .16 | .02 | -.51* |
| | | F[d] | -.35 | -.25 | -.08 | -.28 | .38 | .42 | .26 | .05 | .21 | -.29 | .06 | .22 | -.21 | .14 | -.35 |
| Pause | Cards | M[a] | .04 | -.23 | .02 | .01 | .02 | -.33 | -.14 | -.05 | .15 | .59** | .11 | -.42 | -.13 | -.11 | .11 |
| | | F[b] | .11 | .19 | .37 | .43 | .26 | .20 | -.41 | .06 | .27 | .12 | .26 | .30 | -.34 | -.29 | .53* |
| | Cash | M[a] | -.43 | .24 | .14 | .41 | .26 | .07 | -.19 | .02 | .53* | -.25 | .57** | .01 | .19 | .33 | -.48* |
| | | F[b] | -.13 | -.06 | .03 | .04 | -.01 | .21 | .02 | .21 | -.06 | -.42 | -.13 | -.07 | -.30 | -.13 | .06 |
| | MRL-w | M[e] | -.10 | -.20 | .35 | .15 | -.23 | -.02 | -.46 | -.09 | -.31 | .20 | -.17 | -.11 | .42 | .38 | .00 |
| | | F[b] | -.35 | -.43 | -.41 | -.04 | .36 | -.08 | -.01 | -.52* | .26 | -.18 | .13 | .10 | .31 | -.09 | -.07 |
| | MRL-l | M[e] | -.22 | -.43 | .30 | .32 | .08 | .08 | -.33 | -.43 | -.20 | .17 | -.03 | -.03 | .59** | .28 | -.18 |
| | | F[b] | -.46* | -.55** | -.39 | .13 | .53* | -.11 | .26 | -.40 | .43 | -.27 | .49* | .32 | .14 | .27 | -.28 |

*Note.* M = male group; F = female group; Cards = number of cards played before exiting the game; Cash = amount of ‘cash’ ($) won on exiting the game; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]n = 20. [b]n = 21. [c]n = 17. [d]n = 19. [e]n = 18.

*$p < .05$. **$p < .01$.

Table 5.6

*Partial Correlations[a] between Card Perseveration (CP) Task Performance Measures on the Two Tasks and Personality Measures for Both Sexes*

| Task | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | STAI | Fear | SOGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | Cards | M[b] | -.18 | -.04 | .04 | .71** | .54* | .13 | -.01 | -.38 | .65** | .55* | .25 | .27 |
| | | F[c] | .48* | .64** | .60** | .07 | -.13 | .38 | .24 | .50* | -.14 | -.22 | -.07 | -.15 |
| | Cash | M[b] | .29 | .30 | .33 | -.42 | -.53* | .06 | .17 | .35 | -.16 | -.24 | -.56* | -.55* |
| | | F[c] | -.30 | -.47 | -.39 | -.28 | .00 | -.20 | -.05 | -.13 | -.01 | .14 | -.10 | .05 |
| | MRL-w | M[d] | .10 | .27 | -.15 | .06 | .01 | .18 | .37 | .26 | .11 | -.11 | .01 | -.08 |
| | | F[e] | -.41 | -.48 | .03 | -.04 | .52* | .44 | -.03 | -.26 | .37 | .16 | .18 | -.51* |
| | MRL-l | M[d] | -.03 | .23 | .02 | .23 | .24 | .26 | .26 | -.05 | .44 | -.04 | -.04 | .11 |
| | | F[e] | -.37 | -.29 | .03 | -.21 | .51* | .39 | .05 | -.11 | .32 | .14 | .23 | -.45 |
| Pause | Cards | M[b] | .10 | .07 | .14 | .00 | .16 | .04 | -.01 | .03 | .41 | .36 | -.30 | -.04 |
| | | F[c] | .18 | .29 | .47 | .49* | .32 | .43 | -.03 | .31 | .39 | .39 | .45 | -.26 |
| | Cash | M[b] | -.30 | .34 | -.04 | .36 | .19 | -.12 | -.21 | -.04 | .57* | .57** | -.24 | .01 |
| | | F[c] | .04 | .03 | .18 | .11 | -.04 | .14 | .14 | .24 | -.09 | -.13 | -.09 | -.42 |
| | MRL-w | M[f] | .00 | -.18 | .30 | .11 | -.21 | .14 | -.53* | -.08 | -.25 | -.12 | -.03 | .44 |
| | | F[c] | -.32 | -.42 | -.38 | -.04 | .35 | -.13 | -.04 | -.62** | .25 | .13 | .10 | .31 |
| | MRL-l | M[f] | -.08 | -.43 | .24 | .25 | .09 | .25 | -.32 | -.43 | -.18 | -.01 | -.02 | .60* |
| | | F[c] | -.46 | -.61** | -.41 | .28 | .64** | -.34 | .04 | -.60** | .48* | .52* | .30 | .00 |

*Note.* M = male group; F = female group; Cards = number of cards played before exiting the game; Cash = amount of 'cash' ($) won on exiting the game; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]The following variables were controlled for: Lie scale score, age, and order. [b]n = 20. [c]n = 21. [d]n = 17. [e]n = 19. [f]n = 18.

*$p < .05$. **$p < .01$.

In terms of mean response latency (following wins and losses), examination of Table 5.6 shows that a higher Sensitivity to Punishment (i.e., BIS) score was significantly related to a slower mean response latency following losses on the Standard task, $r(14) = .51, p < .05$, consistent with prediction, but only for the female group. A higher score on this same scale was also significantly related to a slower mean response latency following wins on the Standard task, $r(14) = .52, p < .05$, again for the female group only. Also for the female group only on this same task, a higher BAS Fun Seeking score was near significantly related to a faster mean response latency following wins, $r(14) = -.48, p = .06$, and, although not significant, the correlation between scores on this scale and mean response latency following losses was in the same direction, $r(14) = -.29, p > .05$.

For the female group only on the Pause task, a higher BAS Fun Seeking score and Extraversion score were significantly related to a faster mean response latency following losses, $r(16) = -.61, p < .01$, and, $r(16) = -.60, p < .01$, respectively, and a higher Extraversion score was significantly related to a faster mean response latency following wins, $r(16) = -.62, p < .01$. In contrast, for this same group on this same task, a higher Sensitivity to Punishment (i.e., BIS) score, STAI (i.e., BIS) score and Neuroticism score were significantly related to a slower mean response latency following losses, $r(16) = .64, p < .01$, $r(16) = .52, p < .05$, and, $r(16) = .48, p < .05$, respectively. A higher score on the Psychoticism score was significantly related to a faster mean response latency following wins on the Pause task, $r(13) = -.53, p < .05$, but only for the male group.

### *5.3.2 Slot machine simulations*

Two cases, both female, with extremely high z scores (beyond the $p = .001$ criterion of 3.29, two-tailed) on mean response latency on the slot machine with low percentage payback rate were found to be univariate outliers. The outliers were deleted, leaving 40 cases for analysis: 21 males, 19 females. Means and standard deviations of total credits bet and mean response latency across the two slot machine simulations are shown in Table 5.7.

Table 5.7

*Mean and Standard Deviation of Performance Measures across the Two Slot Machine Simulations*

| Measure | Slot Machine Simulation | | | |
|---|---|---|---|---|
| | High Payback Rate | | Low Payback Rate | |
| | Mean | SD | Mean | SD |
| Total credits bet (no.) | 203 | 49.93 | 152 | 32.00 |
| Mean response latency (sec) | 1.73 | 0.65 | 0.92 | 0.36 |
| Mean response latency following wins (sec) | 1.96 | 0.81 | 1.39 | 0.73 |
| Mean response latency following losses (sec) | 1.18 | 0.38 | 0.72 | 0.22 |

*Note.* n = 40; Total credits bet (no.) = total number of credits bet over the 100 trials; Mean response latency = mean response latency between the reels of the slot machine simulation stopping and the next bet placed in seconds; Mean response latency following wins = mean response latency between the reels of the slot machine simulation stopping on a winning combination of symbols and the next bet placed in seconds; Mean response latency following losses = mean response latency between the reels of the slot machine simulation stopping on a losing combination of symbols and the next bet placed in seconds.

### *5.3.2.1 Percentage payback rate effects on slot machine simulation performance*

Mixed MANOVA revealed significant multivariate effects for the main effect of Simulation on the two dependent measures of performance, $F(2, 37) = 79.09, p < .01$; Wilks' Lambda = .19. Follow-up ANOVAs revealed that the two simulations differed both in terms of total credits bet, $F(1, 38) = 51.62, p < .01$, and mean response latency, $F(1, 38) = 123.18, p < .01$. Examination of means in Table 5.7 indicates that, consistent with prediction, a lower total number of credits was bet and mean response latency was faster on the simulation with a low percentage payback rate (means = 152 and 0.92-s, respectively) than on the simulation with a high percentage payback rate (means = 203 and 1.73-s, respectively). There was no significant main effect of Sex, $F(2, 37) = 1.66$, $p > .05$; Wilks' Lambda = .92, and no significant interaction between Sex and Simulation, $F(2, 37) = 1.72, p > .05$; Wilks' Lambda = .92.

*5.3.2.2 Effects of wins/losses on response latency*

*5.3.2.2.1 Slot machine simulation with high percentage payback rate*

ANOVA revealed a significant main effect of Outcome, $F(1, 38) = 66.74, p < .01$. Examination of means in Table 5.7 indicates that, as predicted, mean response latency was faster following losses (1.18-sec) than following wins (1.96-sec). There was no significant interaction between Sex and Outcome, $F(1, 38) = 2.27, p > .05$. However, there was a significant main effect of Sex, $F(1, 38) = 4.18, p < .05$. Mean response latency across both sexes is shown in Figure 5.6. Examination of Figure 5.6 indicates that mean response latency following both outcomes (wins and losses) was faster for males than for females.

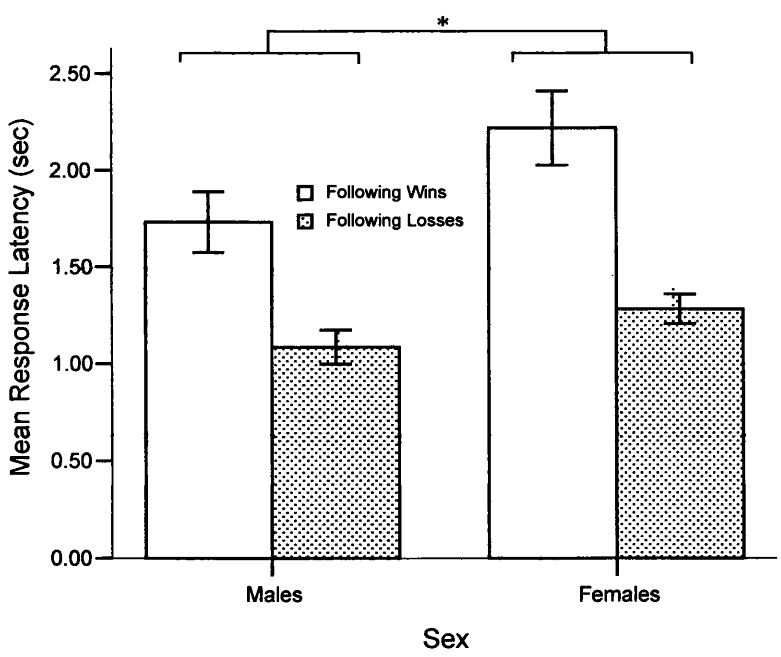


*Figure 5.6.* Mean response latency ( ± 1 SE) following wins and losses on slot machine simulation with high percentage payback rate for males (n = 21) and females (n = 19).

*$p < .05$.

*5.3.2.2.2 Slot machine simulation with low percentage payback rate*

ANOVA revealed a significant main effect of Outcome, $F(1, 38) = 57.43, p < .01$. Examination of means in Table 5.7 indicates that, consistent with prediction, mean response latency was faster following losses (0.72-sec) than following wins (1.39-sec). There was no significant main effect of Sex, $F(1, 38) = 1.35, p > .05$, and no significant interaction between Sex and Outcome, $F(1, 38) = 1.28, p > .05$.

*5.3.2.3 Personality and slot machine simulation performance*

Table 5.8 shows correlations between dependent measures of slot machine simulation performance on the two simulations and personality measures, age, and sex. Due to the presence of a significant correlation between the EPQ-RS Lie scale and total credits bet on the simulation with a low payback rate, $r(39) = -.35, p < .05$, Table 5.8 also shows partial correlations, controlling for Lie scale score, between the dependent measures of slot machine simulation performance on the two tasks and personality measures, age, and sex.

Partial correlations shown in Table 5.8 revealed, as expected, a significant correlation between total credits bet on the simulation with low payback rate and a measure of BIS activity. However, contrary to prediction, a higher score on the STAI was related to a higher total number of credits bet on the simulation with low payback rate, $r(36) = .37, p < .05$. Also contrary to prediction, a higher score on the Sensitivity to Punishment scale (another measure of BIS activity) was near significantly related to a higher total number of credits bet on this same simulation, $r(36) = .31, p = .06$, and no measure of BIS activity (BIS scale of the BIS/BAS Scales, Sensitivity to Punishment scale of the SPSRQ, STAI trait anxiety) was significantly related to total credits bet on the simulation with a high payback rate, $p > .05$.

Table 5.8

*Correlations between Slot Machine Simulation Performance Measures on the Two Simulations and Personality Measures, Age, and Sex*

| Slot Machine Simulation | Measure | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High payback | Total bet | -.19 | -.04 | -.04 | -.03 | .11 | .03 | .05 | -.13 | .10 | -.17 | -.06 | .11 | -.03 | -.03 | .08 |
| | MRL | .18 | .08 | .21 | .09 | .05 | .13 | .02 | .00 | -.04 | .12 | -.13 | .09 | .06 | .15 | .29 |
| | MRL-w | .18 | .08 | .20 | .09 | .03 | .11 | .00 | -.03 | -.04 | .12 | -.12 | .08 | .07 | .15 | .29 |
| | MRL-l | .12 | .06 | .19 | .04 | .15 | .18 | .13 | .16 | -.03 | .03 | -.14 | .13 | -.02 | .09 | .23 |
| Low payback | Total bet | -.17 | -.08 | -.06 | .13 | .34* | .03 | .04 | -.16 | .44** | -.35* | .40* | .15 | .30 | -.04 | .00 |
| | MRL | .09 | .06 | .21 | .05 | .11 | .24 | .23 | .15 | -.05 | .04 | -.20 | .08 | -.05 | .12 | .18 |
| | MRL-w | .12 | .10 | .23 | .03 | .07 | .24 | .22 | .13 | -.04 | .05 | -.20 | .05 | -.10 | .14 | .18 |
| | MRL-l | .03 | -.02 | .14 | .05 | .15 | .22 | .23 | .17 | -.06 | .01 | -.18 | .12 | .02 | .09 | .15 |
| High payback[a] | Total bet | -.17 | -.07 | -.04 | -.02 | .09 | -.06 | .02 | -.16 | .07 | — | -.09 | .07 | -.06 | -.05 | .07 |
| | MRL | .17 | .11 | .22 | .08 | .07 | .21 | .04 | .02 | -.02 | — | -.11 | .12 | .08 | .16 | .30 |
| | MRL-w | .17 | .11 | .21 | .09 | .05 | .19 | .02 | -.01 | -.02 | — | -.10 | .11 | .10 | .17 | .30 |
| | MRL-l | .11 | .07 | .19 | .04 | .15 | .23 | .14 | .17 | -.03 | — | -.13 | .14 | -.01 | .09 | .24 |
| Low payback[a] | Total bet | -.13 | -.17 | -.06 | .17 | .31 | -.17 | -.02 | -.23 | .41* | — | .37* | .08 | .24 | -.07 | -.02 |
| | MRL | .08 | .07 | .21 | .04 | .11 | .30 | .24 | .16 | -.04 | — | -.20 | .09 | -.05 | .13 | .18 |
| | MRL-w | .11 | .12 | .23 | .03 | .07 | .30 | .24 | .14 | -.03 | — | -.19 | .06 | -.09 | .15 | .19 |
| | MRL-l | .03 | -.01 | .14 | .05 | .15 | .26 | .23 | .18 | -.06 | — | -.18 | .13 | .02 | .10 | .15 |

*Note.* n = 39; Total bet = total number of credits bet over the 100 trials; MRL = mean response latency between the reels of the slot machine simulation stopping and the next bet placed; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]Partial correlations controlling for Lie scale score.

*$p < .05$. **$p < .01$.

As expected, a significant correlation was obtained for total credits bet on the simulation with low payback rate and Neuroticism, $r(36) = .41, p < .05$. However, the positive sign of this correlation relates to a higher score on the Neuroticism scale being associated with a higher total number of credits bet on the simulation with low payback rate, contrary to prediction. Also contrary to prediction, the Neuroticism scale was not significantly related to total credits bet on the simulation with high payback rate, $p > .05$, and the Extraversion scale of the EPQ-RS was not significantly related to this dependent variable on either slot machine simulation, $p > .05$.

Contrary to prediction, FSS Fear was not significantly related to total credits bet on either of the two simulations, $p > .05$, and neither was any measure of BAS activity (Sensitivity to Reward scale of the SPSRQ, BAS Drive, BAS Reward Responsiveness, and BAS Fun Seeking scales of the BIS/BAS Scales), $p > .05$. Also contrary to prediction, no personality measure was significantly related to mean response latency following losses on either of the two simulations, $p > .05$.

*5.3.2.4 Simulation differences on associations between personality and total credits bet*

*5.3.2.4.1 BIS/BAS Scales*

ANCOVA revealed no significant interaction between Simulation and BAS Drive, $F(1, 34) = 1.23$, $p > .05$, Simulation and BAS Fun Seeking, $F(1, 34) = 0.20, p > .05$, Simulation and BAS Reward Responsiveness, $F(1, 34) = 0.22, p > .05$, or between Simulation and BIS, $F(1, 34) = 1.15, p > .05$, contrary to prediction.

*5.3.2.4.2 Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ)*

ANCOVA revealed no significant interaction between Simulation and Sensitivity to Punishment, $F(1, 36) = 0.42, p > .05$, and no significant interaction between Simulation and Sensitivity to Reward, $F(1, 36) = 0.01, p > .05$, contrary to prediction.

*5.3.2.4.3 Revised Eysenck Personality Questionnaire short scale (EPQ-RS)*

ANCOVA revealed no significant interaction between Simulation and Extraversion, $F(1, 34) = 0.38$, $p > .05$, and no significant interaction between Simulation and Neuroticism, $F(1, 34) = 1.63$, $p > .05$, contrary to prediction. There was no significant interaction between Simulation and Psychoticism, $F(1, 34) = 0.01$, $p > .05$, and no significant interaction between Simulation and Lie, $F(1, 34) = 0.01$, $p > .05$.

*5.3.2.4.4 Spielberger State-Trait Anxiety Inventory (STAI)*

ANCOVA revealed a significant interaction between Simulation and STAI, $F(1, 37) = 5.17$, $p < .05$. This suggests that, as expected, the response of total credits bet to BIS (as measured by this scale) differed according to Simulation. Figure 5.7 displays the correlation between total credits bet and BIS on both slot machine simulations. The regression lines in the left and right panels (simulation with high payback rate and simulation with low payback rate, respectively) of Figure 5.7 indicate that although, in general, there was a slight trend toward the predicted association between STAI score and total credits bet (i.e., higher STAI score, lower total number of credits bet) on the simulation with high payback rate, a higher score on the STAI was related to a higher total number of credits bet on the simulation with low payback rate, $p < .05$, contrary to prediction.

*5.3.2.4.5 Fear Survey Schedule (FSS)*

ANCOVA revealed no significant interaction between Task and Fear, $F(1, 37) = 0.01$, $p > .05$, contrary to prediction.

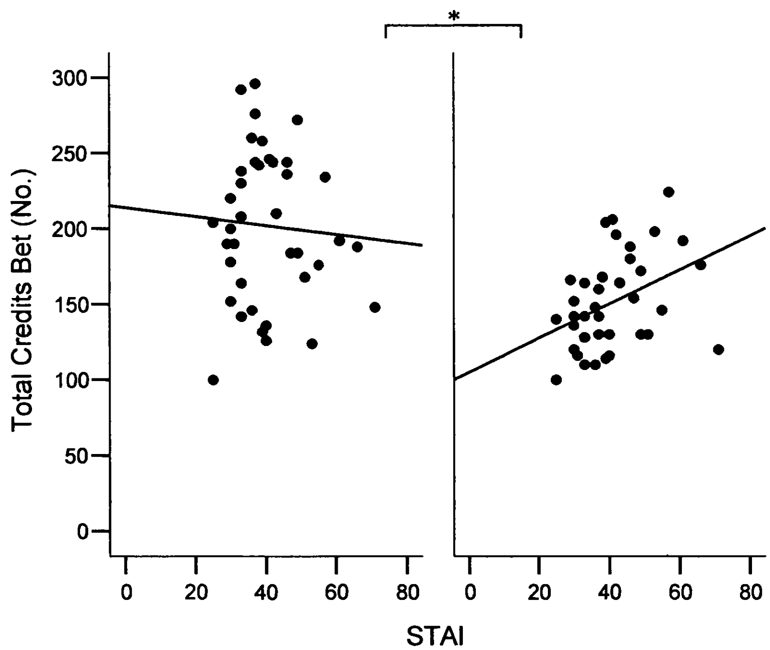


*Figure 5.7.* Spielberger State-Trait Anxiety Inventory (STAI) scores and total number of credits bet (with regression line) for high percentage payback rate (left panel) and low percentage payback rate (right panel) slot machine simulations.

*$p < .05$.

*5.2.3.5 Personality and affect following slot machine simulation performance*

Table 5.9 shows correlations between the two dependent measures of affect following both slot machine simulations and personality measures, age and sex. There were no significant associations between age or sex and the two dependent measures of affect following either of the two simulations, $p > .05$. A higher BAS Drive score was significantly related to a higher positive affect following performance of the simulation with high payback rate, $r(39) = .32$, $p < .05$, and following performance of the simulation with low payback rate, $r(39) = .34$, $p < .05$. In contrast, a higher Sensitivity to Punishment (i.e., BIS) score, STAI (i.e., BIS) score and Neuroticism score were significantly related to higher negative affect following performance of the simulation with high payback rate, $r(39) = .33$, $p < .05$, $r(39) = .49$, $p < .01$, and, $r(39) = .34$, $p < .05$, respectively, and following performance of the simulation with low payback rate, $r(39) = .40$, $p < .05$, $r(39) = .49$,

$p < .01$, and, $r(39) = .39$, $p < .05$, respectively. A higher BIS score and a higher Fear score were also significantly related to higher negative affect following performance of the simulation with low payback rate, $r(39) = .36$, $p < .05$, and, $r(39) = .48$, $p < .01$, respectively.

Table 5.9

*Correlations between Positive and Negative Affect following the Two Simulations and Personality Measures, Age, and Sex*

| Measure | Positive Affect High Payback | Positive Affect Low Payback | Negative Affect High Payback | Negative Affect Low Payback |
|---|---|---|---|---|
| BAS Drive | .32* | .34* | -.09 | .03 |
| BAS Fun Seeking | .06 | -.06 | .03 | -.05 |
| BAS Reward Responsiveness | .22 | .09 | .05 | .21 |
| BIS | .11 | .04 | .18 | .36* |
| Sensitivity to Punishment | -.06 | -.22 | .33* | .40* |
| Sensitivity to Reward | .24 | .16 | .00 | .03 |
| Psychoticism | -.01 | .08 | .06 | -.19 |
| Extraversion | .13 | .05 | -.07 | -.23 |
| Neuroticism | .01 | -.18 | .34* | .39* |
| Lie | -.04 | .20 | -.24 | -.14 |
| State-Trait Anxiety Inventory | .11 | -.02 | .49** | .49** |
| FSS Fear | .16 | -.16 | .22 | .48** |
| South Oaks Gambling Screen | .27 | .14 | .14 | .10 |
| Age | .16 | .00 | -.05 | -.06 |
| Sex | -.12 | -.30 | .06 | -.01 |

*Note.* n = 39; High Payback = slot machine simulation with high percentage payback rate; Low Payback = slot machine simulation with low percentage payback rate.

*$p < .05$. **$p < .01$.

*5.3.2.6 Sex and associations between personality and slot machine simulation performance*

Table 5.10 shows correlations between the dependent measures of slot machine simulation performance on the two simulations and personality measures and age for both males and females. Due to the presence of a significant correlation between the EPQ-RS Lie scale and total credits bet on the simulation with low payback rate for the female group, $r(19) = -.58$, $p < .01$, partial correlations, controlling for Lie scale score, between the dependent measures of slot machine simulation performance on the two tasks and personality measures and age for both males and females are shown in Table 5.11.

Examination of Table 5.11 reveals that, even when analysed separately between sexes, no personality measure was significantly related to total credits bet on the simulation with a high payback rate, $p > .05$, consistent with initial findings shown in Table 5.8 (both groups analysed together) but contrary to prediction. Also contrary to prediction, a higher Sensitivity to Punishment (i.e., BIS) score, STAI (i.e., BIS) score and Neuroticism score were significantly related to a higher total number of credits bet on the simulation with low payback rate, $r(17) = .50, p < .05$, $r(17) = .60$, $p < .01$, and, $r(17) = .59, p < .01$, respectively. However, these significant correlations were obtained for the male group only. For the female group only, on the simulation with low payback rate, a higher Sensitivity to Reward (i.e., BAS) score was significantly related to a lower total number of credits bet, $r(16) = -.57, p < .05$, and a higher BAS Reward Responsiveness score was near significantly related to a lower total number of credits bet, $r(16) = -.45, p = .06$, contrary to prediction.

The only personality measure revealed to be significantly related to mean response latency following losses on the simulation with high payback rate was the SOGS, for the female group only, $r(16) = -.50, p < .05$. The negative sign of this correlation reflects a higher SOGS score being associated with a faster mean response latency following losses on this simulation. The only personality measure revealed to be significantly related to mean response latency following losses on the simulation with low payback rate was the Psychoticism scale, again for the female group only, $r(16) = .53, p < .05$. The positive sign of this correlation reflects a higher Psychoticism score being associated with a slower mean response latency following losses on this simulation.

Table 5.10

*Correlations between Slot Machine Simulation Performance Measures on the Two Simulations and Personality Measures and Age for Both Sexes*

| Slot Machine Simulation | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | Fear | SOGS | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High payback | Total bet | M[a] | -.04 | -.00 | -.03 | .11 | .34 | .11 | .35 | -.31 | .24 | -.09 | .20 | .21 | -.02 | .03 |
| | | F[b] | -.31 | -.08 | -.09 | -.18 | -.18 | -.02 | -.19 | .04 | -.11 | -.27 | -.36 | -.01 | -.02 | -.08 |
| | MRL | M[a] | -.07 | -.13 | .25 | .27 | .25 | .32 | .01 | -.09 | .04 | .02 | .06 | .17 | .45* | .26 |
| | | F[b] | .37 | .33 | .03 | -.06 | -.18 | .13 | .19 | -.04 | -.09 | .27 | -.21 | -.15 | -.34 | .12 |
| | MRL-w | M[a] | -.09 | -.15 | .25 | .28 | .25 | .30 | -.01 | -.11 | .06 | .03 | .08 | .16 | .45* | .24 |
| | | F[b] | .36 | .32 | .03 | -.05 | -.20 | .11 | .15 | -.10 | -.11 | .27 | -.21 | -.15 | -.28 | .15 |
| | MRL-l | M[a] | .01 | -.05 | .21 | .18 | .22 | .33 | .12 | -.02 | -.02 | -.01 | -.06 | .17 | .36 | .28 |
| | | F[b] | .22 | .21 | .05 | -.10 | .06 | .17 | .29 | .30 | .01 | .12 | -.14 | -.04 | -.52* | -.09 |
| Low payback | Total bet | M[a] | .01 | .10 | .17 | .33 | .52* | .18 | -.05 | -.24 | .61** | -.20 | .62** | .23 | .15 | -.01 |
| | | F[b] | -.35 | -.34 | -.47* | -.13 | .05 | -.21 | .14 | -.05 | .13 | -.58** | .10 | .10 | .53* | -.08 |
| | MRL | M[a] | .00 | -.04 | .13 | .21 | .07 | .33 | .15 | .02 | -.13 | -.02 | -.21 | .19 | .27 | .06 |
| | | F[b] | .16 | .17 | .24 | -.12 | .16 | .29 | .43 | .24 | .12 | .13 | -.13 | -.11 | -.44 | .23 |
| | MRL-w | M[a] | .05 | .02 | .13 | .17 | .06 | .35 | .22 | .02 | -.12 | .01 | -.20 | .14 | .20 | .02 |
| | | F[b] | .17 | .20 | .30 | -.09 | .08 | .27 | .34 | .17 | .12 | .11 | -.14 | -.13 | -.42 | .31 |
| | MRL-l | M[a] | -.08 | -.11 | .12 | .26 | .08 | .28 | .05 | .02 | -.14 | -.05 | -.21 | .23 | .36 | .13 |
| | | F[b] | .11 | .09 | .10 | -.16 | .25 | .29 | .50* | .30 | .10 | .11 | -.09 | -.05 | -.41 | .09 |

*Note.* M = male group; F = female group; Total bet = total number of credits bet over the 100 trials; MRL = mean response latency between the reels of the slot machine simulation stopping and the next bet placed; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]n = 20. [b]n = 19.

* $p < .05$. ** $p < .01$.

Table 5.11

*Partial Correlations[a] between Slot Machine Simulation Performance Measures on the Two Simulations and Personality Measures and Age for Both Sexes*

| Slot Machine Simulation | Measure | Sex | BD | BFS | BRR | BIS | SP | SR | P | E | N | STAI | Fear | SOGS | Age |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| High payback | Total bet | M[b] | -.05 | -.05 | -.04 | .12 | .33 | .06 | .34 | -.32 | .23 | .18 | .20 | -.03 | .02 |
| | | F[c] | -.25 | -.05 | -.05 | -.15 | -.21 | -.14 | -.24 | -.01 | -.14 | -.38 | -.05 | -.28 | .15 |
| | MRL | M[b] | -.07 | -.14 | .25 | .27 | .26 | .41 | .02 | -.09 | .05 | .07 | .19 | .45 | .26 |
| | | F[c] | .31 | .30 | -.02 | -.10 | -.17 | .26 | .24 | .01 | -.07 | -.22 | -.12 | -.28 | .15 |
| | MRL-w | M[b] | -.08 | -.16 | .25 | .28 | .26 | .39 | -.01 | -.10 | .07 | .10 | .19 | .46* | .25 |
| | | F[c] | .30 | .30 | -.03 | -.09 | -.20 | .24 | .21 | -.05 | -.08 | -.22 | -.12 | -.21 | .18 |
| | MRL-l | M[b] | .01 | -.06 | .21 | .18 | .22 | .41 | .12 | -.02 | -.02 | -.06 | .18 | .36 | .28 |
| | | F[c] | .19 | .19 | .03 | -.12 | .06 | .23 | .32 | .33 | .02 | -.14 | -.02 | -.50* | -.09 |
| Low payback | Total bet | M[b] | -.01 | .01 | .15 | .34 | .50* | .07 | -.10 | -.27 | .59** | .60** | .17 | .12 | -.03 |
| | | F[c] | -.21 | -.32 | -.45 | -.07 | .02 | -.57* | .06 | -.19 | .08 | .11 | .04 | .46 | -.15 |
| | MRL | M[b] | .00 | -.05 | .13 | .21 | .07 | .40 | .15 | .02 | -.14 | -.22 | .19 | .27 | .06 |
| | | F[c] | .12 | .15 | .22 | -.14 | .17 | .37 | .46 | .26 | .13 | -.12 | -.09 | -.43 | .25 |
| | MRL-w | M[b] | .05 | .03 | .13 | .17 | .07 | .45 | .23 | .03 | -.12 | -.20 | .16 | .20 | .02 |
| | | F[c] | .14 | .18 | .29 | -.11 | .09 | .34 | .37 | .20 | .13 | -.13 | -.12 | -.40 | .32 |
| | MRL-l | M[b] | -.08 | -.15 | .11 | .26 | .07 | .31 | .04 | .01 | -.16 | -.24 | .22 | .36 | .13 |
| | | F[c] | .08 | .08 | .08 | -.18 | .26 | .36 | .53* | .33 | .11 | -.09 | -.03 | -.39 | .10 |

*Note.* M = male group; F = female group; Total bet = total number of credits bet over the 100 trials; MRL = mean response latency between the reels of the slot machine simulation stopping and the next bet placed; MRL-w = mean response latency following wins; MRL-l = mean response latency following losses; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SP = Sensitivity to Punishment; SR = Sensitivity to Reward; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = State-Trait Anxiety Inventory; SOGS = South Oaks Gambling Screen.

[a]The following variable was controlled for: Lie scale score. [b]n = 20. [c]n = 19.

*$p < .05$. **$p < .01$.

*5.3.2.7 Associations between inhibition measures on and between experimental tasks*

Table 5.12 shows correlations between the two dependent measures of response perseveration (number of cards played and amount of cash won) on the two CP tasks, total credits bet on both slot machine simulations, the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) on all four stop-signal tasks, and Q-inhibition (the participants in the present study also performed the four stop-signal tasks and the Q-task, presented in chapter 4). The two dependent measures of response perseveration were appropriately significantly related to one another on the Standard CP task (i.e., higher number of cards played was related to smaller amount of cash won).

Interestingly, significant correlations were revealed between cards played on the Standard CP task and probability of inhibition on stop-trials on the Punishment, Reward, and Conflict stop-signal tasks, $r(42) = -.32, p < .05$, $r(42) = -.31, p < .05$, and, $r(42) = -.31, p < .05$, respectively. The negative sign of these correlations reflects a lower number of cards played (i.e., lesser response perseveration; stronger inhibitory control) on the Standard CP task being associated with a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on the three modified versions of the stop-signal task. Also, higher probability of inhibition on stop-trials and slower SSRT (i.e., weaker inhibitory control) on the Reward stop-signal task were significantly (or near significantly in the case of SSRT) related to a lower total number of credits bet on the slot machine simulation with low payback rate, $r(40) = -.38, p < .05$, and, $r(40) = .30, p = .06$, respectively. Examination of Table 5.12 shows that neither measure of response perseveration on either CP task was significantly related to total number of credits bet on either of the two slot machine simulations, $p > .05$.

Table 5.12

*Correlations between Inhibition Measures on the Stop-signal Tasks, Q-task, Card Perseveration (CP) Tasks, and Slot Machine Simulations*

| Measure | 1[a] | 2[a] | 3[a] | 4[a] | 5[a] | 6[a] | 7[a] | 8[a] | 9[a] | 10[a] | 11[a] | 12[a] | 13[a] | 14[b] | 15[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Baseline *P* (In)[a] | — | | | | | | | | | | | | | | |
| 2. Baseline SSRT[a] | -.67** | — | | | | | | | | | | | | | |
| 3. Punishment *P* (In)[a] | .68** | -.56** | — | | | | | | | | | | | | |
| 4. Punishment SSRT[a] | -.16 | .59** | -.41** | — | | | | | | | | | | | |
| 5. Reward *P* (In)[a] | .66** | -.31* | .61** | -.06 | — | | | | | | | | | | |
| 6. Reward SSRT[a] | -.40** | .39* | -.24 | .30 | -.59** | — | | | | | | | | | |
| 7. Conflict *P* (In)[a] | .59** | -.32* | .72** | -.25 | .73** | -.39* | — | | | | | | | | |
| 8. Conflict SSRT[a] | -.28 | .48** | -.45** | .51** | -.37* | .45** | -.66** | — | | | | | | | |
| 9. Q-(In)[a] | -.02 | -.13 | -.06 | -.01 | -.04 | -.07 | -.07 | -.08 | — | | | | | | |
| 10. Standard cards[a] | -.17 | .00 | -.32* | -.23 | -.31* | -.06 | -.31* | .11 | .01 | — | | | | | |
| 11. Standard cash[a] | -.12 | .05 | .02 | .14 | -.04 | .10 | .06 | -.14 | -.10 | -.62** | — | | | | |
| 12. Pause cards[a] | -.11 | -.13 | -.05 | -.21 | -.18 | -.15 | -.17 | .01 | .02 | .45** | -.05 | — | | | |
| 13. Pause cash[a] | -.10 | -.02 | -.13 | -.06 | -.18 | .15 | -.21 | -.16 | -.04 | .23 | .10 | .09 | — | | |
| 14. High payback total bet[b] | -.27 | .05 | -.22 | .01 | -.26 | .20 | -.17 | -.04 | .19 | .10 | .01 | -.07 | -.18 | — | |
| 15. Low payback total bet[b] | -.15 | -.09 | -.05 | -.11 | -.38* | .30 | -.21 | .08 | .07 | .00 | .17 | -.04 | .08 | .49** | — |

*Note.* Baseline = Baseline stop-signal task; Punishment = Punishment stop-signal task; Reward = Reward stop-signal task; Conflict = Conflict stop-signal task; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; Q-(In) = Q-inhibition; Standard cards = number of cards played before exiting the Standard CP task; Standard cash = amount of 'cash' won on exiting the Standard CP task; Pause cards = number of cards played before exiting the Pause CP task; Pause cash = amount of 'cash' won on exiting the Pause CP task; High payback total bet = total number of credits bet over the 100 trials on the slot machine simulation with high percentage payback rate; Low payback total bet = total number of credits bet over the 100 trials on the slot machine simulation with low percentage payback rate.

[a]n = 42. [b]n = 40.

**p* < .05. ***p* < .01.

## 5.4 Discussion

The present study aimed to investigate inhibitory control on two types of computerised gambling tasks, namely the card perseveration (CP) task and the slot machine simulation, and its association with personality. More specifically, the aim was to investigate response perseveration on the CP task and the influence of a forced pause between response feedback and the opportunity to make another response, the influence of percentage payback (i.e., overall rate of reinforcement) on gambling behaviour on a computerised slot machine simulation, and the association of personality. Toward this end, the two CP tasks described in detail in chapter 2, section 2.1.3, were used to assess response perseveration on both a 'Standard' and a 'Pause' version of the task and the two slot machine simulations described in chapter 2, section 2.1.4, were used to assess gambling behaviour on both a simulation with a high percentage payback rate (70%) and a simulation with a low percentage payback rate (30%).

As expected, significant evidence was produced in support of the prediction that response perseveration should be lesser (i.e., inhibitory control should be stronger) on the CP task with forced pause than on the standard task. Participants played a lower number of cards and won a greater amount of cash on the CP task with forced pause than on the standard task, indicating that the forced 5-s pause imposed following response feedback on the 'Pause' task resulted in greater attention to immediate response feedback on each trial and, thus, an earlier awareness of the changing task contingencies. These results were in accordance with Newman et al.'s (1987) findings for their control group of participants who played fewer cards and won more money on the task with a cumulative feedback display accompanied by a 5-s waiting period (during which they were prevented from making another response) than on the task with immediate feedback only (i.e., the standard task). Newman et al. 'reasoned that forcing subjects to pause after response feedback would improve their use of information about the changing probability of punishment and would reduce perseveration' (p. 146). The results obtained in the present study demonstrated that perseveration was reduced through forcing participants to pause after response feedback even without the presence of a cumulative display of information about the changing probability of punishment.

Also as expected, significant evidence was produced in support of the prediction that a lower total number of credits should be bet on the slot machine simulation with low percentage payback rate than on the simulation with high percentage payback rate. These findings indicate that the high rate of punishment on the simulation with low percentage payback rate resulted in more cautious gambling behaviour, in an attempt to minimise overall loss. The results run contrary to Weatherly and Brandt's (2004) finding that participants' gambling behaviour did not vary as a function of payback percentage. Whereas Weatherly and Brandt employed three different percentage payback values (75%, 83% and 95%) on the slot machine simulations in their study, only two different values were employed in the present study: (1) a high percentage payback rate of 70%; and (2) a low percentage payback rate of 30%. The results obtained suggest that gambling behaviour on computerised slot machine simulations can vary as a function of percentage payback rate, so long as sufficiently varied rates are employed, and that perhaps the three different rates used in Weatherly and Brandt's study were simply not varied enough to produce significantly different gambling behaviour.

It was predicted, based on previous research (Goudriaan et al., 2005), that participants should slow down after drawing a losing card compared to after drawing a winning card on the standard CP task. However, participants' mean response latency was found to be faster following losses than it was following wins, indicating that they were in fact speeding up after drawing a losing card compared to after drawing a winning card, contrary to prediction and to the results obtained by Goudrian et al. with their control group. This effect was revealed for both CP tasks (Standard and Pause) and, although unexpected and contrary to previous findings (Goudriaan et al., 2005), similar effects have been observed on other forms of computerised (as well as on real commercial) gambling tasks such as video poker simulations (Dixon & Schreiber, 2002) and slot machines (Dixon & Schreiber, 2004; Schreiber & Dixon, 2001). In fact, consistent with these findings and with prediction, significant evidence was produced in the present study demonstrating that participants' response latency was faster following losing trials than following winning trials on both slot machine simulations. The results obtained suggest that, as with other forms of computerised gambling tasks, losing (i.e., punishing) trials result in faster initiation of the start of the consecutive trial (i.e., faster betting) than winning (i.e., rewarding) trials on the CP task.

A task order effect was observed when assessing mean response latency following wins/losses on the standard CP task and a gender effect was observed when assessing the same dependent measures on the slot machine simulation with high percentage payback rate. Participants that performed the Pause task first had a faster mean response latency following both outcomes (wins and losses) on the standard CP task than those that performed the Standard task first and males had a faster mean response latency following both outcomes than females on the slot machine simulation with high percentage payback rate. However, despite the presence of these order/gender effects, for both groups in both cases, mean response latency was always faster following losses than following wins. Since the slot machine simulation with low percentage payback rate comprised the greatest number of losing trials (70 out of 100), results also showed that participants' overall mean response latency was faster on the simulation with low percentage payback rate than on the simulation with high percentage payback rate, consistent with prediction.

*5.4.1 Card perseveration task performance related to personality*

Confirmatory analyses, investigating associations between personality measures and performance measures for all participants taken together, produced near significant evidence in support of the prediction that higher self-reported BAS activity should be associated with greater response perseveration (i.e., weaker inhibitory control) on the Standard task. A higher score on the BAS Reward Responsiveness scale was related to a higher number of cards played on the Standard task. Although no measure of BAS activity was associated with response perseveration on the Pause task, contrary to prediction, it was actually predicted that, due to the presence of the 5-s forced pause following response feedback, the association between higher self-reported BAS activity and greater response perseveration should be weaker on this task compared to on the Standard task. The lack of any association between BAS activity and response perseveration on the Pause task was, therefore, in line with prediction when considering that a measure of BAS activity (BAS Reward Responsiveness) was found to be related to greater response perseveration on the Standard task. In fact, a higher score on the BAS Fun Seeking scale was revealed to be more strongly associated with greater response perseveration (based on both measures: cards played and cash won) on the Standard task than on the Pause task, providing significant evidence in support of this prediction.

Other predictions included that higher self-reported BAS activity and Extraversion should be associated with faster response latency following losses on the Standard task. These predictions were generated based on previous research (Goudriaan et al., 2005; Newman & Howland, 1986; Newman et al., 1987; Patterson, Kosson, & Newman, 1987) indicating that disinhibited participants are less likely to pause after receiving negative feedback. Since it was predicted that disinhibition (or greater response perseveration) should be associated with higher self-reported BAS activity and Extraversion, it seemed sensible, in light of the previous research just mentioned, to assume also that higher scores on these personality measures should be associated with faster response latency following losses. Consistent with prediction, a higher BAS activity (assessed by the BAS Drive Scale) was found to be related to a faster mean response latency following losses on the Standard task. Extraversion was not found to be significantly related to mean response latency following losses on this task in the confirmatory analyses, contrary to prediction, but then again Extraversion was not found to be related to response perseveration in the confirmatory analyses either, also contrary to prediction, whereas higher BAS activity was related to greater response perseveration (disinhibiton) on the Standard task and so the revelation that higher BAS activity was also related to faster mean response latency following losses on this task was consistent with predictions based on the idea that failure to pause following punishment is related to poorer learning from punished errors (Newman et al. 1987).

Higher BAS activity (assessed by the BAS Drive scale) was also revealed to be related to faster mean response latency following wins on the Standard task, indicating a general failure to pause following response feedback (both punishing as well as rewarding) on the CP task being associated with higher BAS reactivity. This same association was revealed on the Pause version of the task too: higher BAS activity was related to faster mean response latency following losses (based on BAS Drive and BAS Fun Seeking scale scores) as well as following wins (based on BAS Fun Seeking scale score). Higher Extraversion was also related to faster mean response latency following losses as well as wins on this same task. However, participants were forced to pause for 5-s following response feedback on each trial on this version of the CP task and the results indicated that, despite higher BAS activity still being associated with faster mean response latency (following the 5-s forced pause) following both losses as well as wins on the Pause task (as it was on the Standard task), higher BAS activity was no longer related to greater response perseveration (as it was on the Standard task) on the Pause task which suggests that the forced pause following response feedback was effective in strengthening learning from punished errors.

Exploratory analyses revealed additional evidence in support of the prediction that higher self-reported BAS activity should be associated with greater response perseveration on the Standard task. However, these analyses also revealed some intriguing order and gender differences in these associations. When analysing correlations separately for the two groups that performed the tasks in different orders (Standard task first or Pause task first), a higher score on each of the BAS measures employed (except the Sensitivity to Reward scale of the SPSRQ) was related to greater response perseveration (based on either the number cards played alone, as in the case of the BAS Fun Seeking and BAS Reward Responsiveness scales, or both cards played and cash won, as in the case of the BAS Drive scale) on the Standard task, in line with prediction, but only for the group that performed the Standard task first. No measure of BAS activity or Extraversion was related to response perseveration on either CP task for the group that performed the Pause task first. It seems that the 5-s forced pause following response feedback on the Pause task not only resulted in a weaker association between self-reported BAS activity and response perseveration on this task, as predicted, but also that it had a lasting effect on these associations if this task was performed before the Standard task.

When analysing correlations separately for both sexes in the exploratory analyses, a higher score on the Extraversion scale as well as on each of the BAS measures employed (except the Sensitivity to Reward scale of the SPSRQ) was related to greater response perseveration (based on either the number cards played alone, as in the case of the Extraversion, BAS Drive and BAS Reward Responsiveness scales, or both cards played and cash won, as in the case of the BAS Fun Seeking scale) on the Standard task, in line with prediction, but only for female participants. For males, self-reported BAS activity was not related to response perseveration on either CP task. The significant relations between Extraversion, BAS measures and response perseveration were not present for the female group on the Pause task, suggesting that the 5-s forced pause following response feedback on this task had the effect of weakening associations between higher self-reported BAS activity, Extraversion and greater response perseveration, consistent with prediction.

In previous research, response perseveration on the CP task has been explained in terms of Newman and Wallace's (1993) 'reward dominance' personality dimension. It has been suggested that greater reward dominance results in a reduced tendency to interrupt goal-directed behaviour to evaluate its potential negative consequences, leading to response preservation. Reward dominance can be explained in the context of RST as a heightened BAS activity and a suppressed BIS activity (see Gray, 1991). The results discussed above suggest that a heightened BAS activity was related to greater response perseveration on the standard task for females and for participants that performed this task before the pause version, and that by forcing participants to pause for 5-s following response feedback on the CP task, thus forcing them to interrupt goal-directed behaviour, heightened BAS activity was no longer associated with greater response perseveration. However, as discussed below, the results obtained concerning associations between BIS activity and response perseveration were not consistent with a reward dominance (i.e., a heightened BAS and a suppressed BIS) explanation.

It was predicted that higher self-reported BIS activity, Fear, and Neuroticism should be associated with lesser response perseveration (i.e., stronger inhibitory control) on both CP tasks and that, due to the presence of the 5-s forced pause following response feedback, these associations should be stronger on the CP task with forced pause than on the standard task. However, confirmatory analyses produced significant evidence to suggest that a higher score on the BIS scale, the Sensitivity to Punishment (i.e., BIS) scale and the Neuroticism scale were related to greater response perseveration (i.e., weaker inhibitory control; based on either the number cards played, as in the case of the BIS and Neuroticism scales, or the amount of cash won, as in the case of the Sensitivity to Punishment scale) on the Standard task, contrary to prediction. These associations were not obtained on the Pause task, however. In fact, there was a slight trend toward the opposite, predicted, association between BIS scale score and one of the two dependent measures of response perseveration, amount of cash won, on the Pause task that differed significantly from the association between BIS scale score and amount of cash won on the Standard task (see Figure 5.5). Also, a higher Neuroticism score was related to a greater amount of cash won (i.e., lesser response perseveration) on the Pause task, consistent with prediction. So, although greater BIS reactivity and Neuroticism were unexpectedly associated with greater response perseveration on the standard CP task (for which possible explanations are discussed below; section 5.4.3), forcing participants to pause following response feedback resulted in more theoretically consistent associations between inhibitory control and BIS reactivity/Neuroticism on the CP task.

Exploratory analyses conducted with the aim of investigating further some of the unexpected findings revealed in the confirmatory analyses (discussed above) revealed some intriguing order and gender differences in associations between self-reported BIS activity, Fear, Neuroticism and measures of response perseveration. When analysing correlations separately for the two groups that performed the tasks in different orders (Standard task first or Pause task first), a higher score on the BIS scale, the Sensitivity to Punishment (i.e., BIS) scale and the Neuroticism scale were related to greater response perseveration (based on number of cards played) on the Standard task, consistent with the unexpected findings revealed in the confirmatory analyses (discussed above) and contrary to prediction, but only for the group that performed the Pause task first. Interestingly, for the other group (Standard task first), higher BIS activity (assessed by the Sensitivity to Punishment scale) was related to slower mean response latency following losses, in line with prediction, as well as following wins on the Standard task, indicating that, for this group, higher BIS activity was associated with a greater tendency to pause following response feedback on the Standard task and, as a result, was not associated with greater response perseveration (unlike for the group that performed the Pause task first, where higher BIS activity was not significantly related to slower response latency following losses, contrary to prediction).

Higher BIS activity (assessed by the BIS and Sensitivity to Punishment scales and the STAI) was also found to be related to slower mean response latency following losses on the Pause task, again only for the group that performed the Standard task first. Correspondingly, for this same group of participants, higher BIS activity (assessed by the BIS scale and the STAI) was related to lesser response perseveration (based on amount of cash won) on the Pause task, in line with prediction. Higher Neuroticism was also revealed to be related to lesser response perseveration (based on amount of cash won) on the Pause task, in line with prediction, again only for the group that performed the Standard task first. Although the correlations between these personality measures and amount of cash won on this task were not significant for the other group (Pause task first) they were, however, found to be in the same direction. Since, for this group, evidence was produced to suggest that, contrary to prediction, higher BIS activity and Neuroticism were related to greater response perseveration on the Standard task (discussed above), the discovery that there was a trend toward the opposite, predicted, association between these personality measures and a measure of response perseveration for this group on the Pause task provides further support for the argument that forcing participants to pause following response feedback resulted in more theoretically consistent associations between inhibitory control and BIS reactivity/Neuroticism on the CP task, this time for both groups that performed the tasks in different orders.

When analysing correlations separately for both sexes in the exploratory analyses, higher BIS activity (assessed by the BIS and Sensitivity to Punishment scales and the STAI) and Neuroticism were related to greater response perseveration (based on either the number cards played alone, as in the case of the STAI and the Neuroticism scale, or both cards played and cash won, as in the case of the BIS and Sensitivity to Punishment scales) on the Standard task, consistent with the unexpected findings revealed in the confirmatory analyses and contrary to prediction. In addition, higher Fear was also revealed to be related to greater response perseveration (based on amount of cash won) on this same task, contrary to prediction. However, these unexpected correlations were obtained for the male group only. Interestingly, for the female group, higher BIS activity (assessed by the Sensitivity to Punishment scale) was related to slower mean response latency following losses, in line with prediction, as well as following wins on the Standard task, indicating that, for female participants, higher BIS activity was associated with a greater tendency to pause following response feedback on the Standard task and, as a result, was not associated with greater response perseveration (unlike for the male group, where higher BIS activity was not significantly related to slower response latency following losses, contrary to prediction). Also, significant evidence was produced in line with prediction for the male group on the Pause task: higher BIS activity (assessed by the STAI) and Neuroticism were related to lesser response perseveration (based on amount of cash won), providing further support for the argument that forcing participants to pause following response feedback resulted in more theoretically consistent associations between inhibitory control and BIS reactivity/Neuroticism on the CP task, for male participants at least.

Higher BIS activity (assessed by the BIS scale) was related to greater response perseveration (based on number of cards played) on the Pause task, contrary to prediction, for the female group. However, this personality measure was not significantly related to greater response perseveration for females on this task based on amount of cash won. Nevertheless, the finding that a measure of BIS activity was positively correlated with a measure of response perseveration for the female group was yet another unexpected finding concerning the relationship between BIS reactivity and inhibitory control on the CP task.

*5.4.2 Slot machine simulation performance related to personality*

Neither the confirmatory analyses, investigating associations between personality measures and measures of gambling behaviour for all participants taken together, nor the exploratory analyses investigating associations separately for both sexes, produced significant evidence in support of the predictions that higher self-reported BAS activity and Extraversion should be associated with a higher total number of credits bet, as well as with a faster response latency following losses, on the simulation with high percentage payback rate. Correlations between self-reported PANAS scores following performance of this simulation and personality measures were examined in exploratory analyses in an attempt to investigate one possible reason for these unexpected findings: the possibility that the high percentage payback rate present on this slot machine simulation was not as rewarding as expected for highly BAS reactive and extraverted participants.

The issue of putative appetitive tasks possibly eliciting frustrative non-reward (aversive motivation) in certain participants who have high initial expectations of reward, leading to apparently theoretically inconsistent relationships between reactions to (assumed) rewarding situations and BAS activity, was discussed in detail in relation to some unexpected findings concerning personality and stop-signal task performance in chapter 4, section 4.4.3. The finding that higher self-reported BAS activity (assessed by the BAS Drive scale) was related to higher self-reported positive affect following performance of the simulation with high payback rate, however, would dispute this possibility in the present study since a higher positive affect indicates a more positive mood and, thus, a more rewarding experience. However, as pointed out in chapter 4, section 4.4.3, clearly PANAS scores do not provide evidence of initial expectations compared to actual perceived experiences.

No significant evidence was obtained to support the predictions that, due to the lower overall rate of positive reinforcement, the association between higher self-reported BAS activity and Extraversion and higher total number of credits bet should be weaker on the slot machine simulation with low payback rate than on the simulation with high payback rate. However, as discussed above, self-reported BAS activity and Extraversion were not associated with total number of credits bet on the simulation with high payback rate (possibly due to the simulation not being as rewarding as initially expected; see above), contrary to prediction, and so it was no surprise that the association between these self-report personality measures and total credits bet was not found to be significantly weaker on the simulation with low payback rate, after all.

Although the confirmatory analyses revealed no relation between BAS activity, Extraversion, and total number of credits bet or mean response latency following losses on the slot machine simulation with low percentage payback rate, contrary to prediction, significant associations were revealed in the exploratory analyses for the female group of participants. However, these associations were also found to be contrary to prediction: higher BAS activity (assessed by the Sensitivity to Reward and BAS Reward Responsiveness scales) was related to a lower total number of credits bet on this slot machine simulation for females. Again, these apparently theoretically inconsistent relationships could be due to participants, particularly females, perceiving playing the slot machine simulations as less rewarding than initially expected. The idea was that participants would be exposed to a high level of reward initially on the slot machine simulation in the first condition (high payback rate), thus activating the BAS and resulting in more risky gambling behaviour (i.e., a greater number of maximum bets placed and so a higher total number of credits bet) and that this risky gambling behaviour would then continue for highly BAS reactive and Extraverted participants on the slot machine simulation in the second condition (low payback rate) despite the low level of reward. However, if highly BAS reactive and Extraverted participants found the simulation with high payback rate less rewarding than initially expected for one reason or another, then this could have elicited frustrative non-reward (aversive motivation) for these participants (see Corr 2002a). Being presented with yet another slot machine simulation (low payback rate) would then most likely heighten the aversive motivation, leading to the apparently theoretically inconsistent relationships obtained on this second simulation.

It was predicted that higher self-reported BIS activity, Fear, and Neuroticism should be associated with a lower total number of credits bet on both slot machine simulations and that, due to the higher overall level of negative reinforcement, these associations should be stronger on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. However, contrary to prediction, no measure of BIS activity, Fear, or Neuroticism was related to this dependent measure on the simulation with high payback rate and significant evidence was produced to suggest that higher BIS activity (assessed by the STAI and the Sensitivity to Punishment scale) and Neuroticism were actually related to a higher total number of credits bet on the simulation with low payback rate. Examination of simulation differences on associations between personality measures and total credits bet revealed that although there was a slight trend toward higher BIS activity (assessed by the STAI) being associated with a lower total number of credits bet on the simulation with high payback rate, in line with prediction, this association was significantly different on the simulation with low payback rate, but not in the expected direction (see Figure 5.7). Exploratory analyses, conducted in an attempt to investigate further these unexpected findings, revealed that these relationships were present only for the male participants.

The revelation that higher self-reported BIS activity and Neuroticism were related to more risky gambling behaviour on the slot machine simulation with low payback rate was consistent with the unexpected associations found between these personality measures and response perseveration on the standard CP task (see section 5.4.1). Additionally, these unexpected associations were obtained for the male group of participants only on both types of computerised gambling tasks.

### *5.4.3 Possible reasons for unexpected results concerning associations between self-reported Behavioural Inhibition System (BIS) activity and task performance*

The BIS identifies and resolves conflicts between potentially rewarding and punishing stimuli/situations. Such conflict is clearly evident on both types of computerised gambling tasks employed in the present research, and indeed in any type of gambling situation in general, in which potential winning (i.e., rewarding stimuli; drawing a picture card on the CP task or watching the reels of the slot machine simulation stopping on a matching combination of symbols along the 'payline') coexists with possible loss (i.e., punishing stimuli; drawing a number card on the CP task or watching the reels of the slot machine simulation stopping on a mixed combination of symbols along the 'payline'). Although highly BIS reactive individuals, when exposed to conflict, are likely to demonstrate inhibited behaviour in some situations, an approach response may also be initiated in an attempt to avoid punishment (Elliot & Thrash, 2002; McNaughton & Corr, 2004, 2008).

According to revised RST, it is possible for the BIS to resolve a potential reward-punishment conflict situation by engaging the organism in an approach (rather than inhibited) response (McNaughton & Corr, 2004, 2008). Elliot and Thrash (2002) demonstrated that, in some contexts, individuals with more avoidant temperament may initiate an approach response to avoid punishing situations (i.e., active avoidance). The results obtained in the present study suggest that high BIS and Neuroticism might have been associated with 'chasing' (i.e., trying to gain back money that was lost before) losses on the slot machine simulation with low payback rate and on the standard version of the CP task. If this was indeed the case, it appears that this 'chasing' behaviour on these tasks may reflect a heightened sensitivity to the conflict between reward and punishment (i.e., high BIS activity), expressed through approach, rather than inhibited behaviour. 'Chasing' has been identified as a behavioural attribute characterising pathological gambling (*DSM-IV*; APA, 1994). It could, therefore, be valuable for future research to investigate whether similar associations between self-reported BIS activity, Neuroticism and response perseveration and slot machine simulation gambling behaviour would be observed in pathological gamblers using the same tasks employed in the present study.

To summarise, despite obtaining some unexpected results concerning associations between personality and task performance, the present study demonstrated that imposing a 5-s forced pause following response feedback reduced perseveration on the CP task compared to on the 'standard' version (no forced pause, immediate feedback only) and that, despite previous research suggesting otherwise (Weatherly & Brandt, 2004), participants' gambling behaviour did vary as a function of payback percentage on a computerised slot machine simulation. Limitations of the present study included not assessing levels of reinforcement expectancies in relation to the behavioural tasks. Had these been assessed, possibly using a similar method to that described in Kambouropoulos and Staiger's (2004) study, the results could potentially have been used to explain some of the unexpected findings obtained concerning associations between BAS activity and gambling behaviour on the slot machine simulations. This is one potentially important issue for future research to investigate.

Another limitation was that the gambling related tasks employed, unlike real commercial gambling machines/games, lacked monetary rewards/punishments. Clearly greater ecological validity would have been achieved with the use of monetary task contingencies, providing participants with the opportunity to win, lose, and keep real cash winnings. Unfortunately, however, due to limited financial resources, this was not possible in the present study and, instead, participants were informed that their winnings from each of the tasks would be compared with the average individual's winnings and that, therefore, they should try to finish with as much 'cash' (on the CP tasks) or 'credits' (on the slot machine simulations) as possible. It was anticipated that, although participants were not playing for real money, by informing them of the above, they would be sufficiently motivated to view the tasks, as well as the cash/credits, seriously. The results obtained concerning task differences, discussed above, suggest that this was indeed the case, since despite the absence of monetary contingencies participants performed the tasks significantly differently and consistent with prediction.

Future research should be directed at investigating pathological gamblers' performance on the tasks employed since it would be valuable to examine the effectiveness of the manipulations (i.e., the 5-s forced pause following response feedback on the CP task; the different percentage payback rates on the two slot machine simulations) on gambling related inhibitory control within a pathological gambling group compared to a non-problem gambling control group (such as that used in the present study). Goudriaan et al. (2005) has demonstrated that pathological gamblers show a greater response perseveration on the standard CP task compared to normal controls. However, no previous research has investigated the effect of a 5-s forced pause following response feedback on pathological gamblers' response perseveration on the CP task. This, along with the investigation of pathological gamblers' inhibitory control and personality on each of the other experimental tasks employed in the present chapter and the previous one, is the subject of the next chapter.

# Chapter 6

# Experimental Study 5:

# Inhibitory Control and Personality in Pathological Gamblers vs. Non-problem Gambling Controls

## 6.1 Aims and experimental predictions

### *6.1.1 Aims*

The aim of this study was to investigate inhibitory control and personality differences in pathological gamblers compared to non-problem gambling controls. Toward this end, the South Oaks Gambling Screen (SOGS; described in chapter 2, section 2.2.7) was used to distinguish pathological gamblers from non-problem gambling controls, the same four stop-signal tasks used in Experiments 2 and 3 of chapter 3 (sections 3.2 and 3.3, respectively) and in chapter 4 were used to assess group differences in inhibitory control across standard as well as modified versions of the stop-signal task, the Q-task (described in chapter 2, section 2.1.2) was used to assess group differences in inhibition (i.e., BIS functioning), the same two card perseveration (CP) tasks employed in chapter 5 were used to assess response perseveration (i.e., inhibitory control) on a 'Standard' as well as a 'Pause' version of this gambling related computerised behavioural task, and the same two computerised slot machine simulations employed in chapter 5 were used to examine group differences in gambling related inhibitory control across slot machine simulations with high (70%) and low (30%) percentage payback rates. The same six personality measures employed in chapters 4 and 5 (BIS/BAS Scales, SPSRQ, STAI Y2 scale, EPQ-RS, FSS, and PANAS) were used for the same purposes as detailed in section 4.1.1.

No previous research has investigated inhibitory control in pathological gamblers using the standard stop-signal task, let alone tasks with different response contingencies. Also, no previous research has investigated inhibition in pathological gamblers using the Q-task, the influence of a forced pause between response feedback and the opportunity to make another response on pathological gamblers' response perseveration on the CP task, or the influence of these two percentage payback rates on pathological gamblers' gambling behaviour using a computerised slot machine simulation.

### *6.1.2 Experimental predictions*

#### *6.1.2.1 Personality*

Strong evidence in the previous literature has related impulsivity (proposed to be linked to the BAS; see Corr, 2004) to PG (see chapter 1, section 1.3.1), leading to the suggestion that, within the context of RST, the disinhibited behaviour characterised by PG may result from hyper-sensitivity to reward. This prompted the prediction that pathological gamblers should be more highly BAS reactive than controls. In addition, it has been argued that problem gamblers are insensitive to punishment in that they fail to cease gambling despite losses, and demonstrate a tendency to persist in gambling/performing more poorly (compared to controls) on decision-making tasks despite potential future punishment (Vitaro et al., 1999). Therefore, it was also predicted that pathological gamblers should be less highly FFFS/BIS reactive than controls.

#### *6.1.2.2 Stop-signal task performance*

Based on growing evidence in the literature of the association between impaired inhibitory control and PG (see chapter 1, section 1.3.1), obtained using behavioural tasks such as the go/no-go task (Goudriaan et al., 2005) and the delayed response task (Dixon et al., 2003), it was predicted that pathological gamblers should demonstrate weaker inhibitory control across the four stop-signal tasks than controls.

Previous research using the four stop-signal tasks (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that, compared to on the Baseline and Punishment tasks, due to the presence of specific rewarding stimuli resulting in an increased motivation on go-trials and, consequently, a decreased care in performance, participants had a weaker inhibitory control, faster mean reaction time (MRT) on go-trials, and poorer go-trial response accuracy on the Reward task. Based on the prediction that pathological gamblers should be hyper-sensitive to reward, it was predicted that these task effects should be stronger for pathological gamblers than for controls. Previous research also demonstrated that, compared to on the Baseline task, due to the presence of specific punishing stimuli resulting in an increased care in performance, participants had a stronger inhibitory control and greater go-trial response accuracy on the Punishment task. Based on the predictions that pathological gamblers should be hypo-sensitive to punishment, it was predicted that these task effects should be weaker for pathological gamblers than for controls.

In terms of Conflict task performance, previous research (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that, due to the presence of both specific rewarding and punishing stimuli resulting in an increased motivation on go-trials combined with an increased care not to make errors: compared to on the Punishment task, participants had a weaker inhibitory control, faster MRT on go-trials, and poorer go-trial response accuracy on the Conflict task; compared to on the Reward task, participants had a stronger inhibitory control, slower MRT on go-trials, and greater go-trial response accuracy on the Conflict task; and compared to on the Baseline task, participants had a similar inhibitory control, faster MRT on go-trials, and similar go-trial response accuracy on the Conflict task. Based on the predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was predicted that these task effects should be: stronger for pathological gamblers than for controls for comparisons with the Punishment task; weaker for pathological gamblers than for controls for comparisons with the Reward task; and different for pathological gamblers than for controls for comparisons with the Baseline task, in that, for pathological gamblers, compared to on the Baseline task, inhibitory control should be weaker, MRT on go-trials should decrease to a greater degree (vs. controls' MRT on go-trials), and go-trial response accuracy should be poorer on the Conflict task.

*6.1.2.3 Q-task performance*

Newman et al. (1997) found that psychopaths (a clinical group characterised by disinhibited behaviour) were shown to display less inhibition than non-psychopathic controls on Q-present trials, consistent with weak BIS models of psychopathy (e.g., Fowles, 1980; Gray, 1987). Since PG has been linked to 'behavioural disinhibition' (McCormick, 1993), and it was predicted that pathological gamblers should be less punishment sensitive (i.e., weaker BIS) than controls, it was predicted that pathological gamblers should display less inhibition than controls on Q-present trials.

*6.1.2.4 Card perseveration (CP) task performance*

Based on previous research demonstrating that pathological gamblers perseverated longer on the CP task compared to normal controls (Goudriaan et al., 2005), it was predicted that this same effect should be observed on the standard task in the present study. It was also predicted that the forced 5-s pause following response feedback on the 'Pause' version of the task should reduce pathological gamblers' relative perseverative deficit. This prediction was based on previous research showing that while psychopaths perseverated to a greater degree than non-psychopaths on the standard CP task, there were no group differences when participants played the task with a cumulative feedback display accompanied by a 5-s waiting period during which they were prevented from making another response (Newman et al., 1987). Although the 'Pause' task employed in the present study was without a cumulative feedback display (it presented immediate feedback only accompanied by a 5-s waiting period during which no responses could be made), the results obtained in chapter 5 demonstrated, in a sample of forty-two adult members of the general public, that it was effective in reducing perseveration (consistent with Newman et al.'s findings with their control group and their modified version of the task; see chapter 1, section 1.3.2.1), and so it was anticipated that it should also be effective in reducing pathological gamblers' relative perseverative deficit.

Goudriaan et al.'s (2005) study demonstrated that their normal control group slowed down after losses, compared to after wins, on the CP task, whereas the PG group did not slow down after losses compared to after wins. However, the study presented in chapter 5 found that, contrary to Goudriaan et al.'s findings but consistent with results obtained on other forms of computerised (as well as on real commercial) gambling tasks such as video poker simulations (Dixon & Schreiber, 2002) and slot machines (Dixon & Schreiber, 2004; Schreiber & Dixon, 2001; study presented in chapter 5), participants responded faster following losses than following wins. Therefore, it was predicted that response latency should be faster following losses than following wins for both groups on the Standard task in the present study, but that this effect should be stronger (i.e., response latency should speed-up following losses compared to following wins to a greater degree) for pathological gamblers than for controls.

*6.1.2.5 Slot machine simulation performance*

Based on previous research using the two slot machine simulations (chapter 5), it was predicted that a lower total number of credits should be bet on the simulation with low percentage payback rate than on the simulation with high percentage payback rate, but that, due to pathological gamblers' predicted hyper-sensitivity to reward and hypo-sensitivity to punishment, this simulation effect should be weaker for pathological gamblers than for controls and pathological gamblers should bet a higher total number of credits than controls across the two simulations.

Also, based on the findings of previous research (Dixon & Schreiber, 2002, 2004; Schreiber & Dixon, 2001; study presented in chapter 5), it was predicted that, for both groups, response latency should be faster following losing trials than following winning trials on both slot machine simulations. Thus, since the simulation with low percentage payback rate comprises a greater number of losing trials, it was also predicted that overall response latency should be faster on this simulation than on the simulation with high percentage payback rate, for both groups.

## 6.2 Method

### *6.2.1 Participants*

Eighty-two adults participated. Forty-two individuals (40 males, 2 females) who were recruited from a betting shop (bookmakers) in Swansea and scored in excess of 4 on the South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987), the most widely used diagnostic tool for pathological gambling, composed the pathological gambling (PG) group. The SOGS has been validated by cross-tabulating scores with both family members' assessments and counsellors' individual ratings and, in addition, SOGS scores correlated strongly with *DSM-IV* (APA, 1994) items for pathological gambling. Scores in excess of 4 on the SOGS are frequently correlated with pathological gambling (Dixon, Marley, & Jacobs, 2003). The mean SOGS score for the PG group was 9.07. Thirty-nine non-problem gambling control participants (19 males, 20 females) were recruited from the general public by means of opportunity sampling methods. Control participants also completed the SOGS and had to score below 3 to be included in the study. The mean SOGS score for the control group was 0.74. Participants' ages ranged between 18 and 48 years (mean = 25.02, S.D. = 7.35) and between 18 and 53 years (mean = 24.85, S.D. = 8.90) for the PG group and the control group, respectively. The two groups were matched on age: there was no significant difference in age between the two groups, $t(79) = 0.10, p > .05$. There was a significant difference in SOGS scores between the PG group (mean = 9.07, S.D. = 2.86) and the control group (mean = 0.74, S.D. = 0.79; equal variances not assumed), $t(47.60) = 18.16, p < .01$. Participants gave their written informed consent to take part in the study after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded £15 cash for their participation.

### *6.2.2 Materials*

#### *6.2.2.1 Personality measures*

Each of the personality measures employed (BIS/BAS Scales, SPSRQ, EPQ-RS, STAI Y2 scale, FSS, PANAS, and SOGS) are described in detail in chapter 2, section 2.2. The South Oaks Gambling Screen (SOGS; Lesieur & Blume, 1987; described in detail in chapter 2, section 2.2.7) was used to distinguish pathological gambling participants from non-problem gambling control participants.

##### *6.2.2.1.1 Descriptive statistics*

Correlations between personality measures for both groups are shown in Table 6.1. These data were similar to those reported in previous psychometric studies with larger samples (Jorm et al. 1999; Perkins et al., 2007; Stinchfield, 2002; Torrubia et al., 2001). Importantly, for both groups, the BIS, Sensitivity to Punishment, STAI, Neuroticism, and FSS Fear scales were correlated as expected with one another and the BAS scales of the BIS/BAS Scales, Sensitivity to Reward, and Extraversion scales were correlated as expected with one another also (except that the Sensitivity to Reward scale of the SPSRQ was not positively correlated with the Extraversion scale of the EPQ-RS, contrary to expectations).

#### *6.2.2.2 Behavioural tasks*

Each of the experimental tasks described in detail in chapter 2, section 2.1, (i.e., Baseline, Punishment, Reward and Conflict stop-signal tasks, Q-task, standard CP task, CP task with forced pause, slot machine simulation with high percentage payback rate, and slot machine simulation with low percentage payback rate) were used in the present study. The written instructions given to participants for each of these experimental tasks are shown in full in Appendices A, E, F, G, H, I, J, K, and L, respectively.

Table 6.1

*Correlations between Personality Measures for Both Groups*

| | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI | FSS | SOGS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pathological Gambling Group ($n$ = 42) | | | | | | |
| BD | — | | | | | | | | | | | | |
| BFS | .52** | — | | | | | | | | | | | |
| BRR | .53** | .12 | — | | | | | | | | | | |
| BIS | -.05 | -.03 | .02 | — | | | | | | | | | |
| SP | .13 | -.11 | .12 | .72** | — | | | | | | | | |
| SR | .38* | .35* | .39* | .32* | .45** | — | | | | | | | |
| P | .28 | .25 | -.02 | -.09 | .18 | .29 | — | | | | | | |
| E | .24 | .42** | .01 | -.22 | -.43** | .07 | -.07 | — | | | | | |
| N | .13 | .06 | -.08 | .63** | .73** | .24 | .24 | -.36* | — | | | | |
| L | .07 | .12 | -.11 | -.17 | -.13 | -.18 | -.03 | -.16 | -.20 | — | | | |
| STAI | .09 | .06 | -.23 | .64** | .75** | .17 | .20 | -.23 | .84** | -.10 | — | | |
| FSS | .29 | .06 | .24 | .60** | .73** | .44** | .23 | -.10 | .53** | -.06 | .55** | — | |
| SOGS | -.13 | .09 | -.42** | .13 | .10 | -.07 | .06 | -.09 | .35* | -.05 | .26 | -.08 | — |
| | | | | | | | Control Group ($n$ = 39) | | | | | | |
| BD | — | | | | | | | | | | | | |
| BFS | .59** | — | | | | | | | | | | | |
| BRR | .37* | .30 | — | | | | | | | | | | |
| BIS | -.32* | -.24 | .12 | — | | | | | | | | | |
| SP | -.46** | -.44** | -.19 | .59** | — | | | | | | | | |
| SR | .22 | .34* | .29 | -.11 | -.06 | — | | | | | | | |
| P | .36* | .47** | -.09 | -.36* | -.19 | .23 | — | | | | | | |
| E | .29 | .47** | .20 | -.34* | -.55** | .13 | .12 | — | | | | | |
| N | -.31 | -.14 | .05 | .65** | .75** | .05 | -.22 | -.29 | — | | | | |
| L | .16 | -.16 | .06 | .17 | -.04 | -.41* | -.18 | -.22 | -.14 | — | | | |
| STAI | -.30 | -.25 | -.11 | .61** | .76** | -.05 | -.21 | -.35* | .81** | -.08 | — | | |
| FSS | -.42** | -.33* | -.07 | .42** | .57** | -.05 | -.34* | -.05 | .41** | -.17 | .48** | — | |
| SOGS | -.18 | -.23 | -.26 | .08 | .04 | .08 | .02 | -.14 | .05 | -.08 | .03 | -.11 | — |

*Note.* BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SR = Sensitivity to Reward; SP = Sensitivity to Punishment; P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = Speilberger Trait Anxiety Inventory; FSS; Fear Survey Schedule; SOGS = South Oaks Gambling Screen.

*$p$ < .05. **$p$ < .01.

### 6.2.3 Design

For both groups (PG and control), the design was identical to that detailed in chapter 4, section 4.2.3. The order of the two slot machine simulations was kept the same across all participants. Each participant performed the slot machine simulation with a high percentage payback rate first followed by the slot machine simulation with a low percentage payback rate. The order of the standard CP task and the CP task with forced pause was counterbalanced across participants in an attempt to minimize any possible conditioned learning effects for these tasks. In each group (PG and control), half of the participants performed the standard CP task first and half of the participants performed the CP task with forced pause first.

### 6.2.4 Procedure

The procedure followed was the same as detailed in chapter 4, section 4.2.4, except that PG participants in the present study were handed, as part of there debrief on completion of the study, written contact details of problem gambling support organisations and help groups (GamCare and Gamblers Anonymous UK) along with a GamCare information leaflet which included information on where they could get help. The order in which the two slot machine simulations were administered and the order in which the two CP tasks were administered, is described in the design section above (section 6.2.3). The data collected and saved from each of the computer tasks for each of the eighty-two participants had to be individually recorded and analysed in spreadsheets.

### 6.2.5 Dependent measures and data analyses of behavioural task performance

#### 6.2.5.1 Dependent measures of stop-signal task performance

See chapter 2, section 2.1.1.5, for detailed descriptions of dependent measures of response inhibition (probability of inhibition on stop-trials and stop-signal reaction time), response execution (go-trial reaction time and go-trial response accuracy) and methods for assessing these dependent measures for each participant on each task.

*6.2.5.2 Dependent measure of Q-task performance*

The dependent measure of interest on the Q-task is Q-inhibition. Q-inhibition is a measurement of the degree to which the Q elicits behavioural inhibition in the test phase of the Q-task. See chapter 2, section 2.1.2.1, for a detailed description of the method for assessing this dependent measure for each participant.

*6.2.5.3 Dependent measures of card perseveration (CP) task performance*

The two dependent measures associated with response perseveration on the CP task comprise: (1) the number of cards played; and (2) the amount of cash won on exiting the task. Two other dependent measures of interest were also yielded from CP task performance: (1) response latency following wins; and (2) response latency following losses. See chapter 2, section 2.1.3.3, for detailed descriptions of these four dependent measures and methods for assessing them for each participant on each task.

*6.2.5.4 Dependent measures of slot machine simulation performance*

There were four dependent measures of interest yielded from slot machine simulation performance: (1) total credits bet; (2) response latency between "pulls"; (3) response latency following winning "pulls"; and (4) response latency following losing "pulls". See chapter 2, section 2.1.4.3, for detailed descriptions of these four dependent measures and methods for assessing them for each participant on each slot machine simulation.

#### *6.2.5.5 Data analyses of group differences in personality*

Between-group differences in scores on the personality measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, BIS, SP, SR, P, E, N, L, STAI, Fear, and SOGS score), as well as age, were assessed with independent *t*-tests.

#### *6.2.5.6 Data analyses of stop-signal task performance*

##### *6.2.5.6.1 Order effects*

Effects of the counterbalancing variable Order on the four dependent measures of stop-signal task performance across Task and between Groups were analysed by mixed multivariate analysis of variance (MANOVA) with Order (Punishment task before Reward task or Reward task before Punishment task) and Group (PG or control) as between-subjects factors. Adjustment was made for four covariates: baseline probability of inhibition on stop-trials, baseline SSRT, baseline MRT on go-trials and baseline go-trial response accuracy. Baseline task performance measures were included as covariates to assess the effect of Order on task performance measures after adjusting for initial differences in stop-signal task performance. The within-subjects factor treated multivariately was the three Tasks performed after the Baseline task: the Punishment, Reward, and Conflict tasks.

There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy). $N = 41$ for the Punishment task before Reward task Order, 40 for the Reward task before Punishment task Order; $N = 42$ for the PG Group, 39 for the Control Group. There was no significant main effect of Order, $F(4, 70) = 0.58, p > .05$; Wilks' Lambda = .97, no significant interaction between Order and Task, $F(8, 66) = 1.46, p > .05$; Wilks' Lambda = .85, and no significant interaction between Order and Group, $F(4, 70) = 0.88, p > .05$;

Wilks' Lambda = .95. Since none of the main effects or interactions involving Order was significant, data were collapsed for subsequent analyses.

*6.2.5.6.2 Task effects*

Task effects on the four dependent measures of stop-signal task performance (the two criterion measures of response inhibition: probability of inhibition on stop-trials and SSRT; and the two criterion measures of response execution: MRT on go-trials and go-trial response accuracy) were analysed by mixed multivariate analysis of variance (MANOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor treated multivariately and Group (PG or control) as the between-subjects factor. Follow-up repeated measure ANOVAs generated by the overall MANOVA were used to analyse Group differences as well as the effect of Group on Task differences (i.e., Group × Task interactions), in each individual dependent measure across Task. Specific hypotheses concerning Group × Task interactions in response inhibition and response execution between individual tasks were tested using simple within-subjects contrasts.

*6.2.5.6.3 Effects of stop-signal delay on probability of inhibition across the two groups*

Effects of stop-signal delay on probability of inhibition on stop-trials were analysed by separate two-way mixed analyses of variance (ANOVA) with Delay (50, 150, 250 and 350-ms) as the within-subjects factor and Group (PG or control) as the between-subjects factor. Polynomial within-subjects contrasts were used to test the hypotheses that probability of inhibition should decrease in a linear fashion across the four stop-signal delays, from 50 to 350-ms, on each stop-signal task.

*6.2.5.7 Data analyses of Q-task performance*

*6.2.5.7.1 Pre-treatment*

Number of incorrect responses in the pre-treatment phase was analysed using an independent *t*-test to determine whether there were group differences in inhibiting button presses to the letter Q.

*6.2.5.7.2 Q-inhibition*

An independent *t*-test was used to compare mean Q-inhibition between the two groups (PG and control).

*6.2.5.8 Data analyses of card perseveration (CP) task performance*

*6.2.5.8.1 Response perseveration*

Group differences in the two dependent measures of response perseveration (cards played and cash won) on the Standard task were analysed by multivariate analysis of variance (MANOVA) with Group (PG or Control) and Order (Standard task first or Pause task first) as between-subjects factors to assess the effects of the counterbalancing variable Order on Group differences in response perseveration. Follow-up two-way ANOVAs generated by the overall MANOVA were used to analyse Group differences in each individual measure of response perseveration.

To test the prediction that the forced 5-s pause following response feedback should reduce pathological gamblers' relative perseverative deficit, the Group × Task interaction was examined from a mixed MANOVA with Task (Standard and Pause) as the within-subjects factor treated multivariately and Group (PG or Control) as a between-subjects factor. Order (Standard task first or Pause task first) was also included as a between-subjects factor to assess the effect of the counterbalancing variable Order on Group differences in response perseveration across Task. Follow-up repeated measure ANOVAs generated by the overall mixed MANOVA were used to examine the Group × Task interaction for each individual measure of response perseveration.

*6.2.5.8.2 Response latency following wins and losses*

Effects of the Outcome of the card drawn on mean response latency on the two tasks were analysed by separate three-way mixed analyses of variance (ANOVA) with Outcome (win and loss) as the within-subjects factor and Group (PG or control) as a between-subjects factor. Order (Standard task first or Pause task first) was also included as a between-subjects factor to assess the effect of the counterbalancing variable Order on mean response latency following wins/losses across Group and Outcome.

*6.2.5.9 Data analyses of slot machine simulation performance*

*6.2.5.9.1 Percentage payback rate effects*

Percentage payback rate effects on two dependent measures of slot machine simulation performance (total credits bet and mean response latency) were analysed by mixed multivariate analysis of variance (MANOVA) with Simulation (high percentage payback rate and low percentage payback rate) as the within-subjects factor treated multivariately and Group (PG or Control) as the between-subjects factor. Follow-up repeated measure ANOVAs generated by the overall MANOVA were used to analyse Group differences as well as the effect of Group on Simulation differences (i.e., Group × Simulation interactions), in each individual dependent measure across Simulation.

*6.2.5.9.2 Response latency following wins and losses*

Effects of the Outcome of the stopped reels on mean response latency on the two simulations were analysed by separate two-way mixed analyses of variance (ANOVA) with Outcome (win and loss) as the within-subjects factor and Group (PG or control) as the between-subjects factor.

**6.3 Results**

*6.3.1 Personality*

The results of the independent *t*-tests are summarised in Table 6.2. Examination of Table 6.2 shows that the two groups were matched on age: there was no significant difference in age between the two groups, $p > .05$. As expected, there was a significant difference in SOGS scores between the PG group (mean = 9.07) and the control group (mean = 0.74) (equal variances not assumed), $t(47.60) = 18.16, p < .01$.

Consistent with prediction, the PG group scored significantly higher on a measure of BAS activity (the Sensitivity to Reward scale; mean = 15.98) than the control group (mean = 11.74), $t(79) = 4.42$, $p < .01$. However, the two groups did not differ significantly in scores on any other measure of BAS activity (BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales), $p > .05$, contrary to prediction. Also contrary to prediction, the two groups did not differ significantly in scores on the Extraversion scale of the EPQ-RS, $p > .05$. The PG group scored significantly higher on the Psychoticism scale (mean = 3.76) than the control group (mean = 2.90), $t(79) = 2.39, p < .05$.

Although the two groups did not differ significantly in scores on the BIS scale, $p > .05$, contrary to prediction, significant between-group differences were revealed for scores on a measure of BIS activity (the STAI), the Neuroticism scale, and FSS Fear, as expected. However, examination of means in Table 6.2 indicates that, contrary to prediction, the PG group scored significantly higher on the STAI (i.e., BIS; mean = 45.40), $t(79) = 2.02, p < .05$, the Neuroticism scale (mean = 7.17), $t(79) = 2.22, p < .05$, and on Fear (mean = 121.19), $t(79) = 2.46, p < .05$, than the control group (mean = 40.41, 5.56, and 90.49, respectively). Also contrary to prediction, the PG group had a near significantly higher Sensitivity to Punishment (i.e., BIS) scale score (mean = 12.50) than the control group (mean = 10.18), $t(79) = 1.91, p = .06$.

Table 6.2

*Mean of Personality Measure Scores and Age for Both Groups, as well as Group Differences in Personality Measure Scores and Age*

| Measure | Group | Mean (± 1 SE) | Group Comparison | | |
|---|---|---|---|---|---|
| | | | df | *t* | *p* |
| South Oaks Gambling Screen | PG[a] | 9.07 ± 0.44 | 47.60 | 18.16** | .00 |
| | Control[b] | 0.74 ± 0.13 | | | |
| BAS Drive | PG[a] | 10.95 ± 0.38 | 79 | 0.50 | .62 |
| | Control[b] | 10.69 ± 0.35 | | | |
| BAS Fun Seeking | PG[a] | 12.55 ± 0.38 | 79 | 0.38 | .71 |
| | Control[b] | 12.33 ± 0.42 | | | |
| BAS Reward Responsiveness | PG[a] | 17.19 ± 0.26 | 79 | 0.03 | .98 |
| | Control[b] | 17.18 ± 0.34 | | | |
| BIS | PG[a] | 20.88 ± 0.59 | 79 | 0.53 | .60 |
| | Control[b] | 20.44 ± 0.60 | | | |
| Sensitivity to Punishment | PG[a] | 12.50 ± 0.80 | 79 | 1.91 | .06 |
| | Control[b] | 10.18 ± 0.93 | | | |
| Sensitivity to Reward | PG[a] | 15.98 ± 0.72 | 79 | 4.42** | .00 |
| | Control[b] | 11.74 ± 0.63 | | | |

Table 6.2 *(cont.)*

| Measure | Group | Mean ( ± 1 SE) | Group Comparison | | |
|---|---|---|---|---|---|
| | | | df | *t* | *p* |
| Psychoticism | PG[a] | 3.76 ± 0.25 | 79 | 2.39* | .02 |
| | Control[b] | 2.90 ± 0.26 | | | |
| Extraversion | PG[a] | 8.67 ± 0.46 | 79 | 0.41 | .68 |
| | Control[b] | 8.95 ± 0.51 | | | |
| Neuroticism | PG[a] | 7.17 ± 0.45 | 79 | 2.22* | .03 |
| | Control[b] | 5.56 ± 0.57 | | | |
| Lie | PG[a] | 2.21 ± 0.22 | 68.29 | 1.81 | .08 |
| | Control[b] | 2.92 ± 0.32 | | | |
| State-Trait Anxiety Inventory | PG[a] | 45.40 ± 1.72 | 79 | 2.02* | .05 |
| | Control[b] | 40.41 ± 1.76 | | | |
| FSS Fear | PG[a] | 121.19 ± 9.31 | 79 | 2.46* | .02 |
| | Control[b] | 90.49 ± 8.20 | | | |
| Age | PG[a] | 25.02 ± 1.13 | 79 | 0.10 | .92 |
| | Control[b] | 24.85 ± 1.43 | | | |

*Note.* PG = Pathological gambling group.

[a]n = 42. [b]n = 39.

*$p < .05$. **$p < .01$.

### *6.3.2 Stop-signal tasks*

#### *6.3.2.1 Task effects on stop-signal task performance between groups*

There were no univariate or multivariate outliers at $p < .001$ based on measures of response inhibition (probability of inhibition on stop-trials and SSRT) or based on measures of response execution (MRT on go-trials and go-trial response accuracy). *N* = 42 for the PG group, 39 for the control group. Means and standard deviations of stop-signal task performance measures across the four tasks for the PG group and the control group are shown in Table 6.3.

Table 6.3

*Mean and Standard Deviation of Stop-signal Task Performance Measures across the Four Tasks for Both Groups*

| Measure | Group | Stop-signal Task | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Baseline | | Punishment | | Reward | | Conflict | |
| | | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| *P* (Inhibition) | PG[a] | 0.62 | 0.16 | 0.70 | 0.15 | 0.47 | 0.20 | 0.56 | 0.16 |
| | Control[b] | 0.59 | 0.17 | 0.66 | 0.15 | 0.49 | 0.16 | 0.57 | 0.15 |
| SSRT (msec) | PG[a] | 257 | 40.35 | 232 | 37.17 | 291 | 53.68 | 252 | 50.62 |
| | Control[b] | 282 | 63.01 | 241 | 49.98 | 271 | 62.50 | 258 | 63.91 |
| MRT (msec) | PG[a] | 514 | 73.78 | 514 | 68.76 | 461 | 71.67 | 464 | 69.31 |
| | Control[b] | 518 | 60.31 | 510 | 63.65 | 460 | 51.52 | 473 | 48.28 |
| No. of errors | PG[a] | 7.86 | 3.33 | 5.26 | 3.46 | 11.07 | 6.49 | 9.81 | 6.96 |
| | Control[b] | 8.33 | 5.93 | 6.10 | 4.86 | 10.15 | 5.39 | 7.92 | 5.87 |

*Note. P* (Inhibition) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; MRT = mean reaction time on go-trials; No. of errors = number of response errors made on go-trials; PG = pathological gambling group.

[a]n = 42. [b]n = 39.

Mixed MANOVA revealed significant multivariate effects for the main effect of Task on the four dependent measures of stop-signal task performance, $F(12, 68) = 53.44, p < .01$; Wilks'

Lambda = .10, and near significant multivariate effects for the Group × Task interaction, $F(12, 68) = 1.81$, $p = .07$; Wilks' Lambda = .76, as expected. However, contrary to prediction, there was no significant main effect of Group, $F(4, 76) = 0.24$, $p > .05$; Wilks' Lambda = .99. Follow-up ANOVAs revealed that the four tasks differed in terms of probability of inhibition on stop-trials (Greenhouse-Geisser correction), $F(2.52, 198.80) = 90.94$, $p < .01$, SSRT, $F(3, 237) = 18.66$, $p < .01$, MRT on go-trials (Greenhouse-Geisser correction), $F(2.54, 200.50) = 137.66$, $p < .01$, and go-trial response accuracy (Greenhouse-Geisser correction), $F(2.40, 189.65) = 32.39$, $p < .01$, and that there was a significant Group × Task interaction involving probability of inhibition on stop-trials (Greenhouse-Geisser correction), $F(2.52, 198.80) = 3.08$, $p < .05$, SSRT, $F(3, 237) = 4.45$, $p < .01$, and go-trial response accuracy (Greenhouse-Geisser correction), $F(2.40, 189.65) = 3.08$, $p < .05$. There was no significant Group × Task interaction for MRT on go-trials (Greenhouse-Geisser correction), $F(2.54, 200.50) = 1.36$, $p > .05$, and no significant between-subjects effects for Group on any of the four dependent variables of task performance, $p > .05$.

##### *6.3.2.1.1 Response inhibition*

###### *6.3.2.1.1.1 Probability of inhibition on stop-trials*

The results of the simple within-subjects contrasts are summarised in Table 6.4. Examination of Table 6.4 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Group when comparing the Punishment task with the Reward task, $F(1, 79) = 4.91$, $p < .05$. This suggests that, as expected, the effect of Task on probability of inhibition on stop-trials differed according to Group when comparing these two tasks. Figure 6.1 displays the mean probability of inhibition on stop-trials across the four tasks for both Groups. Examination of Figure 6.1 indicates that, as expected, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Reward task than on the Punishment task for both groups and that this effect was stronger (i.e., probability of inhibition was reduced to a greater degree from the Punishment task to the Reward task) for the PG group than for the control group, as predicted.

Table 6.4

*Summary of Simple Within-subjects Contrasts Showing Task Effects and Group × Task Interactions when Comparing Individual Tasks for Probability of Inhibition on Stop-trials*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task | *P* (In) | Punishment | P vs. B | 1 | 38.06** | .00 |
| | | | P vs. R | 1 | 231.92** | .00 |
| | | | P vs. C | 1 | 146.81* | .00 |
| | | Conflict | C vs. B | 1 | 10.62** | .00 |
| | | | C vs. R | 1 | 58.41** | .00 |
| | | Reward | R vs. B | 1 | 68.08** | .00 |
| Error | | | | 79 | | |
| Group × Task | *P* (In) | Punishment | P vs. B | 1 | 0.00 | .99 |
| | | | P vs. R | 1 | 4.91* | .03 |
| | | | P vs. C | 1 | 6.15* | .02 |
| | | Conflict | C vs. B | 1 | 3.61 | .06 |
| | | | C vs. R | 1 | 0.27 | .60 |
| | | Reward | R vs. B | 1 | 3.63 | .06 |
| Error | | | | 79 | | |

*Note.* n = 81: 42 in the pathological gambling (PG) group, 39 in the control group; *P* (In) = probability of inhibition on stop-trials; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task; P = Punishment; C = Conflict; R = Reward.

*$p < .05$. **$p < .01$.

Also as expected, there was a significant interaction between Task and Group when comparing the Punishment task with the Conflict task, $F(1, 79) = 6.15$, $p < .05$. Examination of Figure 6.1 indicates that, again as expected, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Conflict task than on the Punishment task for both groups and that this effect was stronger (i.e., probability of inhibition was reduced to a greater degree from the Punishment task to the Conflict task) for the PG group than for the control group, consistent with prediction. There was no significant Group × Task interaction when comparing the Punishment task with the Baseline task, $p > .05$, contrary to prediction.

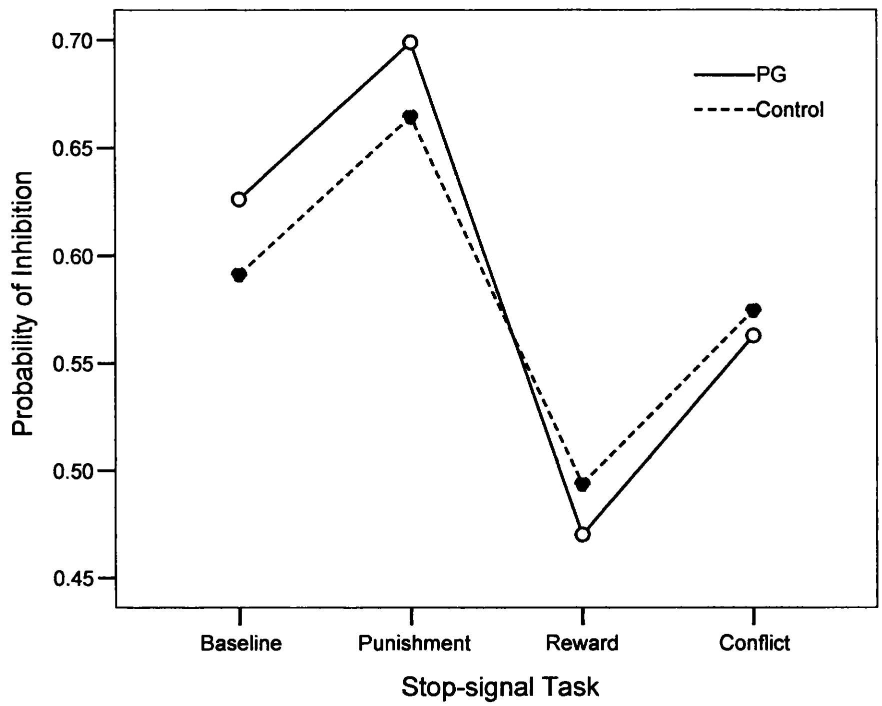


*Figure 6.1.* Mean probability of inhibition on stop-trials across Baseline, Punishment, Reward, and Conflict stop-signal tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

Simple within-subjects contrasts with the Conflict task selected as the reference category revealed a near significant interaction between Task and Group when comparing the Conflict task with the Baseline task, $F(1, 79) = 3.61$, $p = .06$. Examination of Figure 6.1 indicates that, whereas probability of inhibition on stop-trials was slightly lower on the Conflict task than on the Baseline task for the control group, this effect was stronger (i.e., probability of inhibition was reduced to a greater degree from the Baseline task to the Conflict task) for the PG group, consistent with prediction. There was no significant Group × Task interaction when comparing the Conflict task with the Reward task, $p > .05$, contrary to prediction.

Simple within-subjects contrasts with the Reward task selected as the reference category revealed a near significant interaction between Task and Group when comparing the Reward task with the Baseline task, $F(1, 79) = 3.63$, $p = .06$. Examination of Figure 6.1 indicates that, as expected, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Reward task than on the Baseline task for both groups and that this effect was stronger (i.e., probability of inhibition was reduced to a greater degree from the Baseline task to the Reward task) for the PG group than for the control group, as predicted.

*6.3.2.1.1.2 Stop-signal reaction time (SSRT)*

The results of the simple within-subjects contrasts are summarised in Table 6.5. Examination of Table 6.5 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Group when comparing the Punishment task with the Reward task, $F(1, 79) = 4.88$, $p < .05$. This suggests that, as expected, the effect of Task on SSRT differed according to Group when comparing these two tasks. Figure 6.2 displays mean SSRT across the four tasks for both Groups. Examination of Figure 6.2 indicates that, as expected, SSRT was slower (i.e., inhibitory control was weaker) on the Reward task than on the Punishment task for both groups and that this effect was stronger (i.e., SSRT increased to a greater degree from the Punishment task to the Reward task) for the PG group than for the control group, as predicted. Contrary to prediction, no other Group × Task interaction, revealed by simple within-subjects contrasts with the Punishment task selected as the reference category, was significant, $p > .05$.

As expected, simple within-subjects contrasts with the Conflict task selected as the reference category revealed a significant interaction between Task and Group when comparing the Conflict task with the Reward task, $F(1, 79) = 4.86$, $p < .05$. Examination of Figure 6.2 indicates that, again as expected, SSRT was faster (i.e., inhibitory control was stronger) on the Conflict task than on the Reward task for both groups but, contrary to prediction, this effect was stronger (i.e., SSRT decreased to a greater degree from the Reward task to the Conflict task) for the PG group than for the control group. There was no significant Group × Task interaction when comparing the Conflict task with the Baseline task, $p > .05$, contrary to prediction.

Table 6.5

*Summary of Simple Within-subjects Contrasts Showing Task Effects and Group × Task Interactions when Comparing Individual Tasks for Stop-signal Reaction Time (SSRT)*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task | SSRT | Punishment | P vs. B | 1 | 34.22** | .00 |
| | | | P vs. R | 1 | 43.67** | .00 |
| | | | P vs. C | 1 | 9.48** | .00 |
| | | Conflict | C vs. B | 1 | 5.54* | .02 |
| | | | C vs. R | 1 | 17.94** | .00 |
| | | Reward | R vs. B | 1 | 2.69 | .11 |
| Error | | | | 79 | | |
| Group × Task | SSRT | Punishment | P vs. B | 1 | 1.86 | .18 |
| | | | P vs. R | 1 | 4.88* | .03 |
| | | | P vs. C | 1 | 0.05 | .83 |
| | | Conflict | C vs. B | 1 | 2.12 | .15 |
| | | | C vs. R | 1 | 4.86* | .03 |
| | | Reward | R vs. B | 1 | 10.67** | .00 |
| Error | | | | 79 | | |

*Note.* n = 81: 42 in the pathological gambling (PG) group, 39 in the control group; SSRT = stop-signal reaction time; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task; P = Punishment; C = Conflict; R = Reward.

*$p < .05$. **$p < .01$.

As expected, simple within-subjects contrasts with the Reward task selected as the reference category revealed a significant interaction between Task and Group when comparing the Reward task with the Baseline task, $F(1, 79) = 10.67$, $p < .01$. Examination of Figure 6.2 indicates that, whereas SSRT was slightly faster on the Reward task than on the Baseline task for the control group, SSRT was considerably slower (i.e., inhibitory control was weaker) on the Reward task than on the Baseline task for the PG group, consistent with prediction.

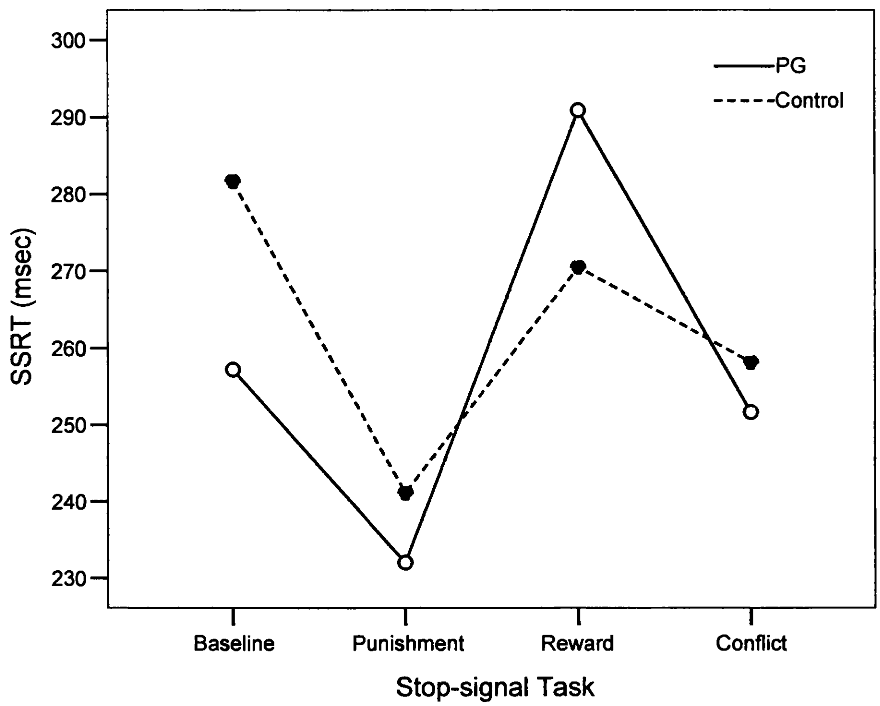


*Figure 6.2.* Mean stop-signal reaction time (SSRT) across Baseline, Punishment, Reward, and Conflict stop-signal tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

*6.3.2.1.2 Response execution*

*6.3.2.1.2.1 Mean reaction time (MRT) on go-trials*

The results of the simple within-subjects contrasts are summarised in Table 6.6. Examination of Table 6.6 shows that simple within-subjects contrasts with the Conflict task selected as the reference category revealed a significant interaction between Task and Group when comparing the Conflict task with the Reward task, $F(1, 79) = 4.29, p < .05$. This suggests that, as expected, the effect of Task on MRT on go-trials differed according to Group when comparing these two tasks. Figure 6.3 displays MRT on go-trials across the four tasks for both Groups. Examination of Figure 6.3 indicates that, whereas MRT on go-trials was slower on the Conflict task than on the Reward task for the control group, this effect was not as strong (i.e., MRT on go-trials increased to a lesser degree from the Reward task to the Conflict task) for the PG group, consistent with prediction. There was no significant Group × Task interaction when comparing the Conflict task with the Baseline task, $p > .05$, contrary to prediction.

Table 6.6

*Summary of Simple Within-subjects Contrasts Showing Task Effects and Group × Task Interactions when Comparing Individual Tasks for Mean Reaction Time (MRT) on Go-trials*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task | MRT | Punishment | P vs. B | 1 | 0.88 | .35 |
| | | | P vs. R | 1 | 221.15** | .00 |
| | | | P vs. C | 1 | 142.39** | .00 |
| | | Conflict | C vs. B | 1 | 171.83** | .00 |
| | | | C vs. R | 1 | 12.87** | .00 |
| | | Reward | R vs. B | 1 | 274.54** | .00 |
| Error | | | | 79 | | |
| Group × Task | MRT | Punishment | P vs. B | 1 | 1.16 | .29 |
| | | | P vs. R | 1 | 0.21 | .65 |
| | | | P vs. C | 1 | 3.07 | .08 |
| | | Conflict | C vs. B | 1 | 0.27 | .61 |
| | | | C vs. R | 1 | 4.29* | .04 |
| | | Reward | R vs. B | 1 | 0.75 | .39 |
| Error | | | | 79 | | |

*Note.* n = 81: 42 in the pathological gambling (PG) group, 39 in the control group; MRT = mean reaction time on go-trials; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task; P = Punishment; C = Conflict; R = Reward.

*$p < .05$. **$p < .01$.

Simple within-subjects contrasts with the Punishment task selected as the reference category revealed a near significant interaction between Task and Group when comparing the Punishment task with the Conflict task, $F(1, 79) = 3.07$, $p = .08$. Examination of Figure 6.3 indicates that, as expected, MRT on go-trials was faster on the Conflict task than on the Punishment task for both groups and that this effect was stronger (i.e., MRT on go-trials decreased to a greater degree from the Punishment task to the Conflict task) for the PG group than for the control group, consistent with prediction. Contrary to prediction, no other Group × Task interaction, revealed by simple within-subjects contrasts with the Punishment or Reward task selected as the reference category, was significant, $p > .05$.

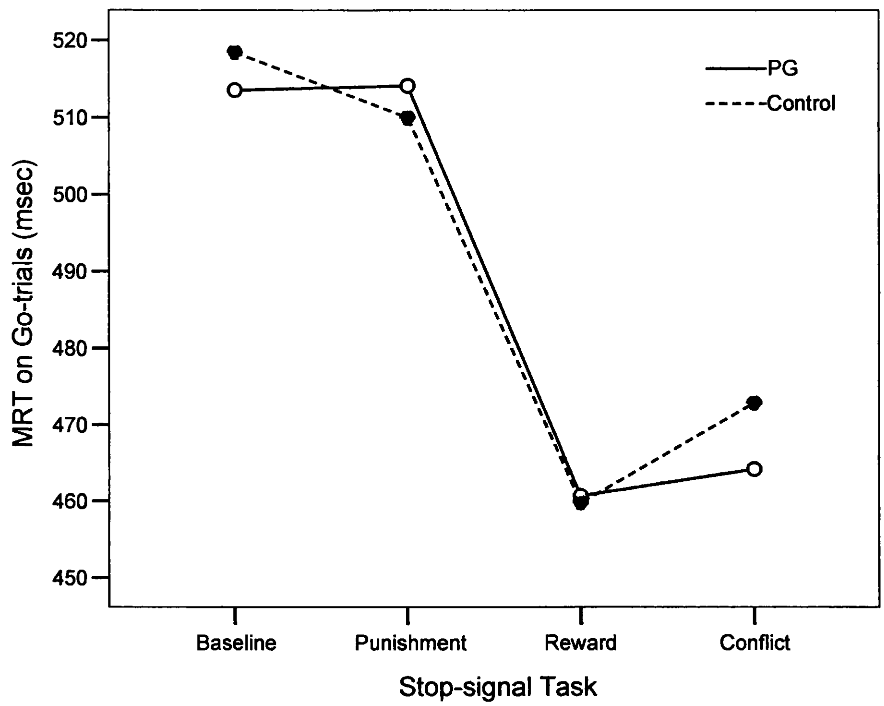


*Figure 6.3.* Mean reaction time (MRT) across Baseline, Punishment, Reward, and Conflict stop-signal tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

*6.3.2.1.2.2 Go-trial response accuracy*

The results of the simple within-subjects contrasts are summarised in Table 6.7. Examination of Table 6.7 shows that simple within-subjects contrasts with the Punishment task selected as the reference category revealed a significant interaction between Task and Group when comparing the Punishment task with the Conflict task, $F(1, 79) = 5.94, p < .05$. This suggests that, as expected, the effect of Task on go-trial response accuracy differed according to Group when comparing these two tasks. Figure 6.4 displays the mean number of response errors made on go-trials across the four tasks for both Groups. Examination of Figure 6.4 indicates that, as expected, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Conflict task than on the Punishment task for both groups and that this effect was stronger (i.e., the number of response errors on go-trials increased to a greater degree from the Punishment task to the Conflict task) for the PG group than for the control group, consistent with prediction.

Table 6.7

*Summary of Simple Within-subjects Contrasts Showing Task Effects and Group × Task Interactions when Comparing Individual Tasks for Go-trial Response Accuracy*

| Source | Measure | Reference Category | Task | df | *F* | *p* |
|---|---|---|---|---|---|---|
| Task | Errors | Punishment | P vs. B | 1 | 38.24** | .00 |
| | | | P vs. R | 1 | 93.22** | .00 |
| | | | P vs. C | 1 | 32.39** | .00 |
| | | Conflict | C vs. B | 1 | 1.81 | .18 |
| | | | C vs. R | 1 | 16.17** | .00 |
| | | Reward | R vs. B | 1 | 20.63** | .00 |
| Error | | | | 79 | | |
| Group × Task | Errors | Punishment | P vs. B | 1 | 0.22 | .64 |
| | | | P vs. R | 1 | 2.96 | .09 |
| | | | P vs. C | 1 | 5.94* | .02 |
| | | Conflict | C vs. B | 1 | 4.24* | .04 |
| | | | C vs. R | 1 | 1.24 | .27 |
| | | Reward | R vs. B | 1 | 1.58 | .21 |
| Error | | | | 79 | | |

*Note.* n = 81: 42 in the pathological gambling (PG) group, 39 in the control group; Errors = number of response errors made on go-trials; Punishment = Punishment task; Conflict = Conflict task; Reward = Reward task; P = Punishment; C = Conflict; R = Reward.

*$p < .05$. **$p < .01$.

There was a near significant interaction between Task and Group when comparing the Punishment task with the Reward task, $F(1, 79) = 2.96, p = .09$. Examination of Figure 6.4 indicates that, as expected, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Reward task than on the Punishment task for both groups and that this effect was stronger (i.e., the number of response errors on go-trials increased to a greater degree from the Punishment task to the Reward task) for the PG group than for the control group, consistent with prediction. There was no significant Group × Task interaction when comparing the Punishment task with the Baseline task, $p > .05$, contrary to prediction.

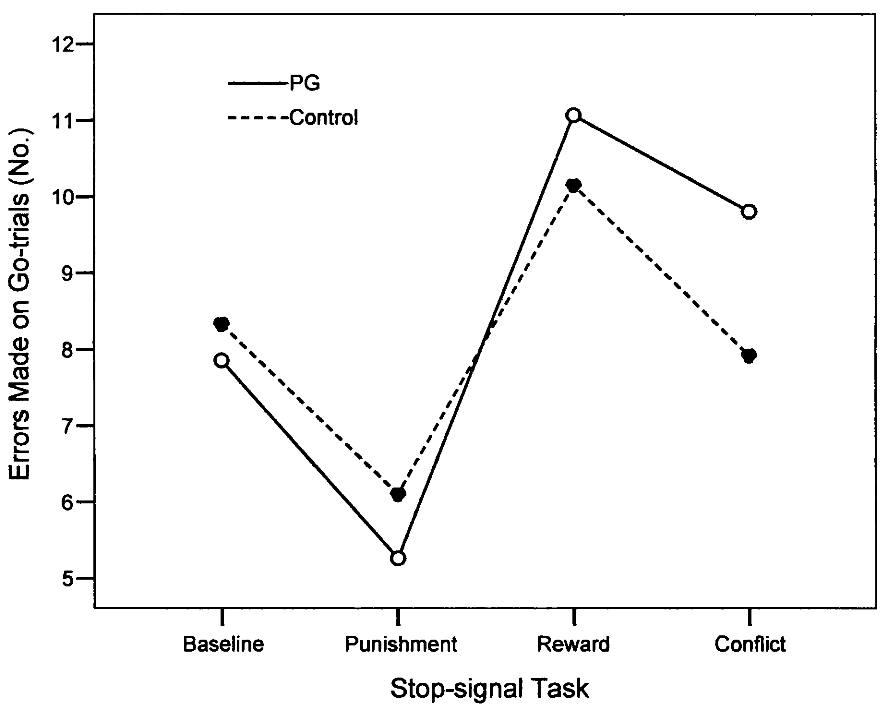


*Figure 6.4.* Mean number of response errors made on go-trials across Baseline, Punishment, Reward, and Conflict stop-signal tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

As expected, simple within-subjects contrasts with the Conflict task selected as the reference category revealed a significant interaction between Task and Group when comparing the Conflict task with the Baseline task, $F(1, 79) = 4.24, p < .05$. Examination of Figure 6.4 indicates that, whereas go-trial response accuracy was similar on these to tasks for the control group, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Conflict task than on the Baseline task for the PG group, consistent with prediction. There was no significant Group × Task interaction when comparing the Conflict task with the Reward task, $p > .05$, contrary to prediction, and simple within-subjects contrasts with the Reward task selected as the reference category revealed no significant Group × Task interaction when comparing the Reward task with the Baseline task, $p > .05$, also contrary to prediction.

*6.3.2.2 Effects of stop-signal delay on probability of inhibition across the two groups*

Mixed ANOVA revealed a significant main effect of Delay on probability of inhibition on stop-trials on the Baseline (Greenhouse-Geisser correction), $F(2.35, 185.75) = 439.96, p < .01$, Punishment (Greenhouse-Geisser correction), $F(2.11, 166.64) = 426.28, p < .01$, Reward (Greenhouse-Geisser correction), $F(2.51, 198.08) = 409.13, p < .01$, and Conflict (Greenhouse-Geisser correction), $F(2.53, 199.96) = 483.39, p < .01$, tasks. Figure 6.5 plots mean probability of inhibition at each stop-signal delay on each of the four stop-signal tasks for both Groups. Although there was no significant main effect of Group on the Baseline, $F(1, 79) = 0.93, p > .05$, Punishment, $F(1, 79) = 1.08, p > .05$, Reward, $F(1, 79) = 0.34, p > .05$, or Conflict, $F(1, 79) = 0.13, p > .05$, task, contrary to prediction, Figure 6.5 indicates that, as expected, probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay for both groups on each task.

The fact that there was no significant Group × Delay interaction on the Baseline (Greenhouse-Geisser correction), $F(2.35, 185.75) = 1.12, p > .05$, Punishment (Greenhouse-Geisser correction), $F(2.11, 166.64) = 0.30, p > .05$, Reward (Greenhouse-Geisser correction), $F(2.51, 198.08) = 0.31, p > .05$, or Conflict (Greenhouse-Geisser correction), $F(2.53, 199.96) = 0.08$, $p > .05$, task indicates that probability of inhibition on stop-trials diminished as a function of increasing stop-signal delay in the same manner for both groups on each task. Polynomial within-subjects contrasts revealed this function to be a significant linear trend on the Baseline, $F(1, 79) = 833.97, p < .01$, Punishment, $F(1, 79) = 740.60, p < .01$, Reward, $F(1, 79) = 1245.57$,

$p < .01$, and Conflict, $F(1, 79) = 1584.24$, $p < .01$, task. This indicates that, as predicted, probability of inhibition decreased in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on each on the four stop-signal tasks for both groups.

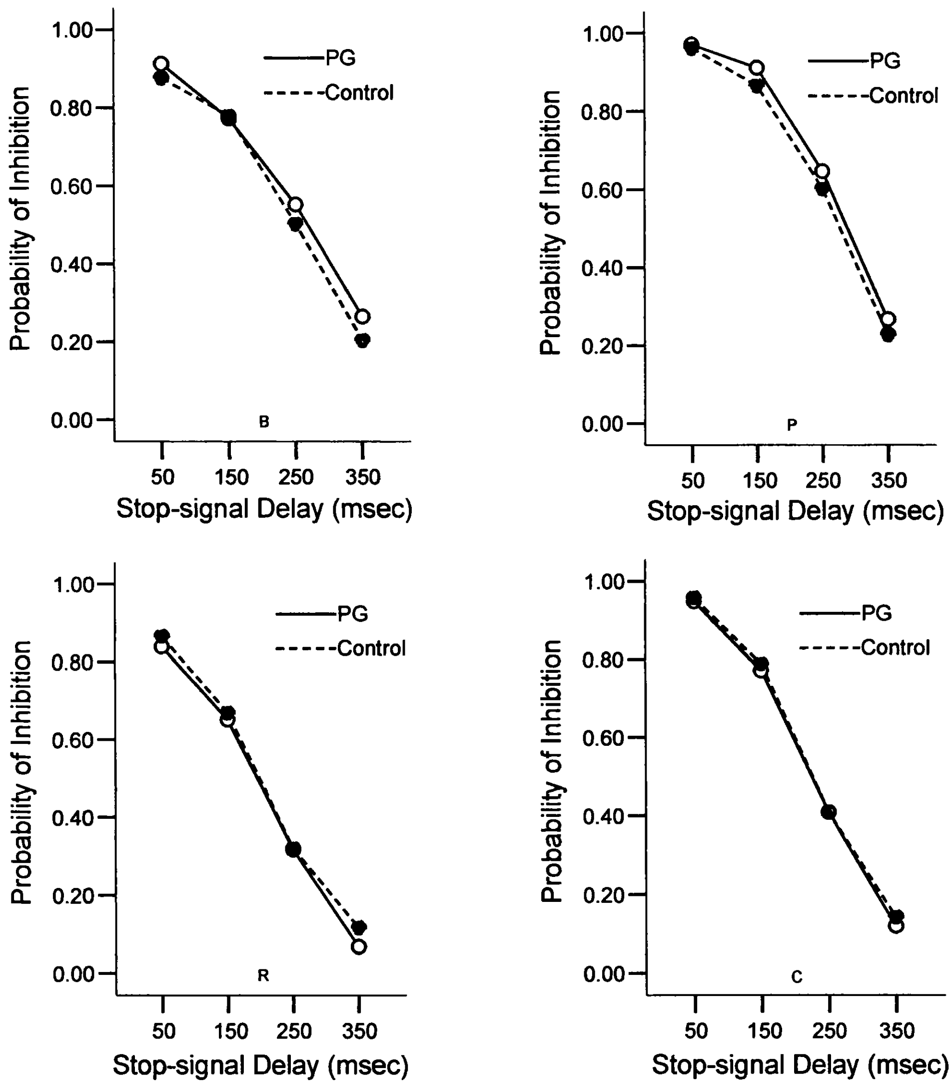


*Figure 6.5.* Mean probability of inhibition at each stop-signal delay for the pathological gambling (PG) group and the control group on the Baseline (panel B), Punishment (panel P), Reward (panel R), and Conflict (panel C) stop-signal tasks.

*6.3.3 Q-task*

*6.3.3.1 Pre-treatment*

There was no significant difference in the number of incorrect responses made in the pre-treatment phase between the PG group (mean = 2.76, S.D. = 1.12) and the control group (mean = 2.46, S.D. = 1.00), $t(79) = 1.27, p > .05$.

*6.3.3.2 Q-inhibition*

Contrary to prediction, there was no significant difference in Q-inhibition between the PG group (mean = 15.84-ms, S.D. = 45.51) and the control group (mean = 6.60-ms, S.D. = 64.80), $t(79) = 0.75$, $p > .05$.

*6.3.4 Card perseveration (CP) tasks*

There were no univariate or multivariate outliers at $p < .001$ based on measures of response perseveration (cards played and cash won). $N = 42$ for the PG Group, 39 for the Control Group; $N = 41$ for the Standard task first Order, 40 for the Pause task first Order. However, for analyses involving mean response latency (following wins and losses) on each of the tasks, some participants (two in the PG group and five in the control group on the Standard task and three in the PG group and two in the control group on the Pause task) exited very early in play and, as a result, were outliers due to a small number of reaction times after losses. The outliers were deleted for analyses involving mean response latency following wins and losses only, leaving 74 cases for analysis on the Standard task (40 in the PG group, 34 in the control group; 38 in the group that performed the Standard task first, 36 in the group that performed the Pause task first) and 76 cases for analysis on the Pause task (39 in the PG group, 37 in the control group; 39 in the group that performed the Standard task first, 37 in the group that performed the Pause task first). Means and standard deviations of CP task performance measures across the two tasks for the PG group and the control group are shown in Table 6.8. Pause task mean response latencies shown in Table 6.8 are presented minus the 5-s forced pause.

Table 6.8

*Mean and Standard Deviation of Card Perseveration (CP) Task Performance Measures across the Two Tasks for Both Groups*

| Measure | Group | CP Task | | | |
|---|---|---|---|---|---|
| | | Standard | | Pause | |
| | | Mean | SD | Mean | SD |
| No. of cards played | PG[a] | 74.79 | 26.09 | 40.19 | 13.77 |
| | Control[b] | 64.13 | 26.98 | 39.28 | 19.27 |
| Cash won ($) | PG[a] | 144 | 106.84 | 278 | 34.98 |
| | Control[b] | 192 | 95.23 | 256 | 56.73 |
| Mean response latency following wins (sec) | PG | 1.71[c] | 0.46[c] | 0.82[b] | 0.27[b] |
| | Control | 1.83[d] | 0.41[d] | 1.03[e] | 0.53[e] |
| Mean response latency following losses (sec) | PG | 1.66[c] | 0.44[c] | 0.74[b] | 0.26[b] |
| | Control | 1.71[d] | 0.38[d] | 0.86[e] | 0.51[e] |

*Note.* No. of cards played = number of cards played before exiting the game; Cash won ($) = amount of 'cash' won on exiting the game; mean response latency following wins = mean response latency between a winning card being drawn and the next card played in seconds; Mean response latency following losses = mean response latency between a losing card being drawn and the next card played in seconds; PG = pathological gambling group.

[a]n = 42. [b]n = 39. [c]n = 40. [d]n = 34. [e]n = 37.

*6.3.4.1 Response perseveration*

MANOVA revealed near significant multivariate effects for the main effect of Group on the two dependent measures of response perseveration on the Standard task, $F(2, 76) = 2.33$, $p = .10$; Wilks' Lambda = .94. Follow-up ANOVAs revealed that the two Groups differed significantly in terms of amount of cash won, $F(1, 77) = 4.46$, $p < .05$, and near significantly in terms of number of cards played, $F(1, 77) = 3.16$, $p = .08$. Examination of means in Table 6.8 indicates that, consistent with prediction, the PG group played a higher number of cards and won a smaller amount of cash (74.79 and $144, respectively) (i.e., showed greater response perseveration) on the Standard task than the control group (64.13 and $192, respectively). There was no significant main effect of Order, $F(2, 76) = 0.91$, $p > .05$; Wilks' Lambda = .98, and no significant interaction between Order and Group, $F(2, 76) = 0.44$, $p > .05$; Wilks' Lambda = .99.

Mixed MANOVA revealed significant multivariate effects for the main effect of Task, $F(2, 76) = 54.56$, $p < .01$; Wilks' Lambda = .41, as well as for the Group × Task interaction, $F(2, 76) = 3.97$, $p < .05$; Wilks' Lambda = .91, as expected. Follow-up ANOVAs revealed that the two Tasks differed both in terms of number of cards played, $F(1, 77) = 110.50$, $p < .01$, and amount of cash won, $F(1, 77) = 63.88$, $p < .01$, and that there was a significant Group × Task interaction involving amount of cash won, $F(1, 77) = 7.77$, $p < .01$, and a near significant Group × Task interaction involving number of cards played, $F(1, 77) = 2.98$, $p = .09$.

The Group × Task interactions involving number of cards played and amount of cash won are plotted in Figures 6.6 and 6.7, respectively. Examination of Figures 6.6 and 6.7 indicates that, as predicted, the Pause task reduced the PG groups' relative perseverative deficit both in terms of number of cards played and amount of cash won.

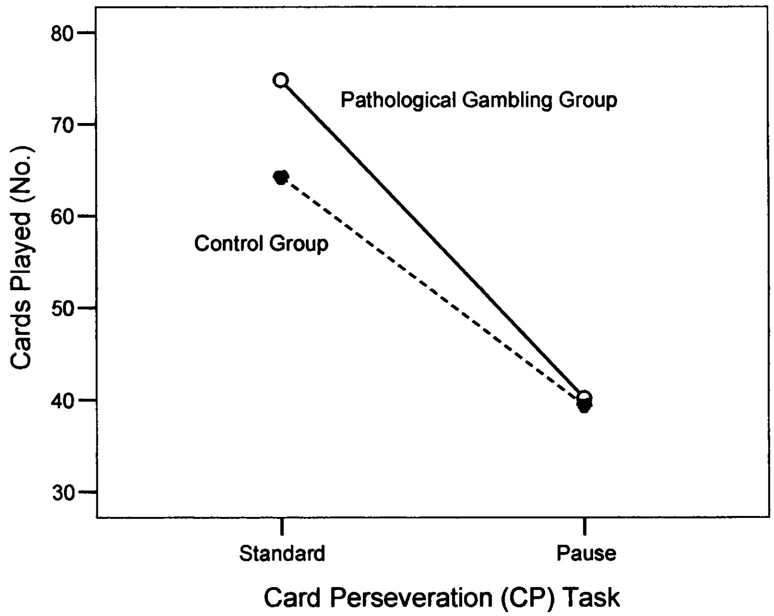


*Figure 6.6.* Interaction plot for number of cards played across Standard and Pause card perseveration (CP) tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

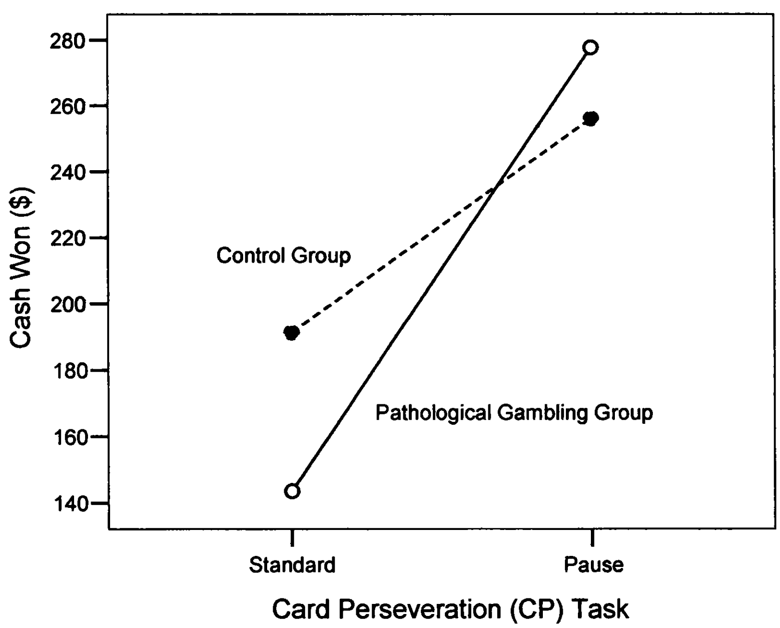


*Figure 6.7.* Interaction plot for amount of cash won across Standard and Pause card perseveration (CP) tasks for the pathological gambling (PG) group (n = 42) and the control group (n = 39).

*6.3.4.2 Response latency following wins and losses*

*6.3.4.2.1 Standard task*

ANOVA revealed a significant main effect of Outcome, $F(1, 70) = 7.93, p < .01$. Examination of means in Table 6.8 indicates that, for both groups, mean response latency was faster following losses (1.66-s for PG group; 1.71-s for control group) than following wins (1.71-s for PG group; 1.83-s for control group), consistent with prediction. However, there was no significant Group × Outcome interaction, $F(1, 70) = 1.34, p > .05$, contrary to prediction. There was no significant main effect of Group, $F(1, 70) = 0.64, p > .05$, Order, $F(1, 70) = 1.48, p > .05$, and no significant Order × Group interaction, $F(1, 70) = 0.80, p > .05$.

*6.3.4.2.2 Pause task*

ANOVA revealed a significant main effect of Outcome, $F(1, 72) = 12.53, p < .01$. Examination of means in Table 6.8 indicates that, for both groups, mean response latency was faster following losses (0.74-s for PG group; 0.86-s for control group) than following wins (0.82-s for PG group; 1.03-s for control group). There was a near significant main effect of Group, $F(1, 72) = 3.45, p = .07$. Mean response latency across the two Groups is shown in Figure 6.8. Examination of Figure 6.8 indicates that mean response latency following both outcomes (wins and losses) on the Pause task was faster for the PG group than for the control group. There was no significant Group × Outcome interaction, $F(1, 72) = 1.56, p > .05$. There was also no significant main effect of Order, $F(1, 72) = 0.18, p > .05$, and no significant Order × Group interaction, $F(1, 72) = 0.84, p > .05$.

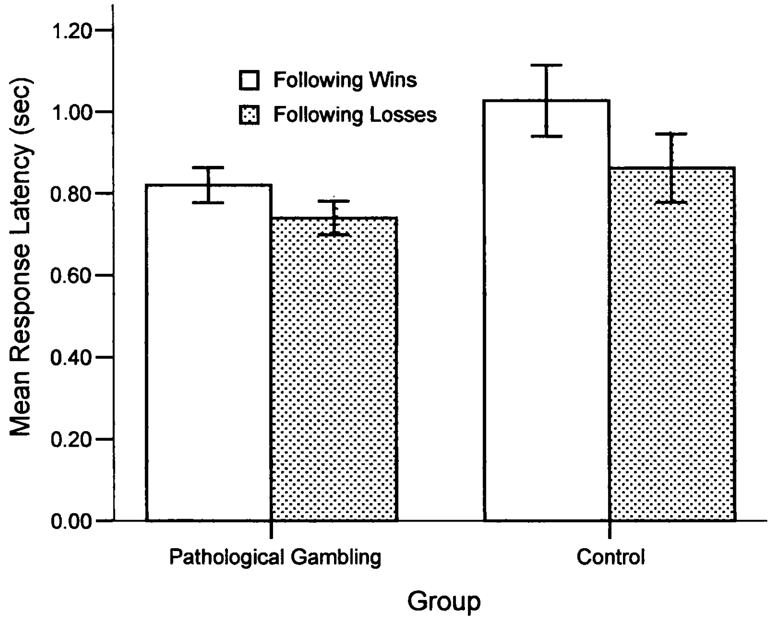


*Figure 6.8.* Mean response latency ( ± 1 SE) following wins and losses on Pause card perseveration (CP) task for pathological gambling (PG) group (n = 39) and control group (n = 37).

*6.3.5 Slot machine simulations*

Two cases, both in the control group, with extremely high z scores (beyond the $p = .001$ criterion of 3.29, two-tailed) on mean response latency on the slot machine with low percentage payback rate were found to be univariate outliers. The outliers were deleted, leaving 79 cases for analysis: 42 in the PG group, 37 in the control group. Means and standard deviations of total credits bet and mean response latency across the two slot machine simulations for both groups are shown in Table 6.9.

*6.3.5.1 Percentage payback rate effects*

Mixed MANOVA revealed significant multivariate effects for the main effects of Simulation, $F(2, 76) = 118.83, p < .01$; Wilks' Lambda = .24, and Group, $F(2, 76) = 17.39, p < .01$; Wilks' Lambda = .69, as expected. Also, near significant multivariate effects were found for the Group × Simulation interaction, $F(2, 76) = 2.90, p = .06$; Wilks' Lambda = .93. Follow-up ANOVAs revealed that the two Simulations differed both in terms of total credits bet, $F(1, 77) = 71.24, p < .01$, and mean response latency, $F(1, 77) = 206.03$, $p < .01$. However, Group differences were significant only for total credits bet, $F(1, 77) = 34.75$, $p < .01$, and the Group × Simulation interaction was significant only for this same dependent measure, $F(1, 77) = 5.87$, $p < .05$. Figure 6.9 plots the Group × Simulation interaction for total number of credits bet.

Table 6.9

*Mean and Standard Deviation of Performance Measures across the Two Slot Machine Simulations for Both Groups*

| Measure | Group | Slot Machine Simulation | | | |
|---|---|---|---|---|---|
| | | High Payback Rate | | Low Payback Rate | |
| | | Mean | SD | Mean | SD |
| Total credits bet (no.) | PG[a] | 239 | 34.72 | 210 | 48.74 |
| | Control[b] | 202 | 51.60 | 149 | 30.97 |
| Mean response latency (sec) | PG[a] | 1.73 | 0.81 | 0.98 | 0.46 |
| | Control[b] | 1.74 | 0.64 | 0.93 | 0.36 |
| Mean response latency following wins (sec) | PG[a] | 1.99 | 0.99 | 1.37 | 0.77 |
| | Control[b] | 1.98 | 0.80 | 1.40 | 0.75 |
| Mean response latency following losses (sec) | PG[a] | 1.13 | 0.45 | 0.81 | 0.36 |
| | Control[b] | 1.20 | 0.37 | 0.73 | 0.22 |

*Note.* Total credits bet (no.) = total number of credits bet over the 100 trials; Mean response latency = mean response latency between the reels of the slot machine simulation stopping and the next bet placed in seconds; Mean response latency following wins = mean response latency between the reels of the slot machine simulation stopping on a winning combination of symbols and the next bet placed in seconds; Mean response latency following losses = mean response latency between the reels of the slot machine simulation stopping on a losing combination of symbols and the next bet placed in seconds; PG = pathological gambling group.

[a]n = 42. [b]n = 37.

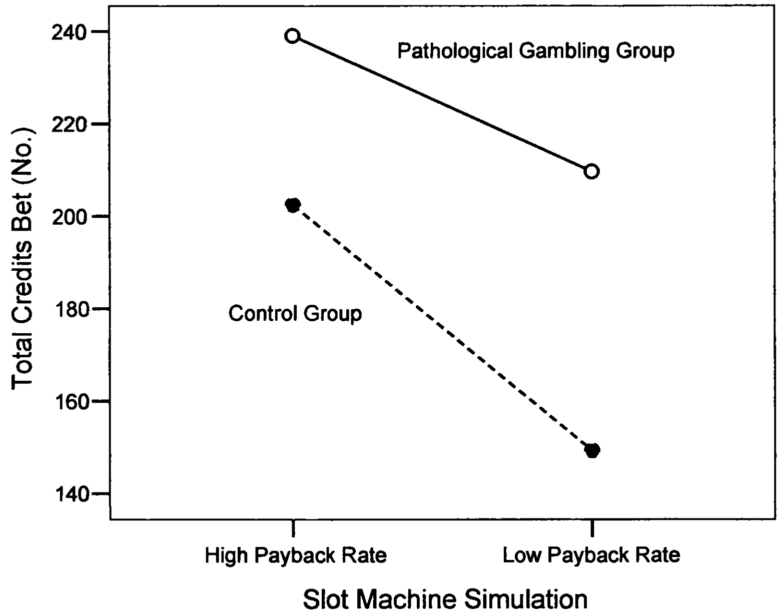


*Figure 6.9.* Interaction plot for total number of credits bet across high percentage payback rate and low percentage payback rate slot machine simulations for the pathological gambling (PG) group (n = 42) and the control group (n = 37).

Examination of Figure 6.9 indicates that while both groups bet a lower total number of credits on the simulation with a low percentage payback rate than on the simulation with a high percentage payback rate, as expected, the PG group bet a higher total number of credits than the control group across both simulations, as predicted, and the decrease in the number of credits bet from the simulation with high payback rate to the simulation with low payback rate was less steep for the PG group than for the control group. This Group × Simulation interaction suggests that the change in percentage payback rate across the two simulations was less effective in reducing the total number of credits bet in the PG group than in the control group, consistent with prediction.

*6.3.5.2 Response latency following wins and losses*

*6.3.5.2.1 Slot machine simulation with high percentage payback rate*

ANOVA revealed a significant main effect of Outcome, $F(1, 77) = 119.79, p < .01$, and no significant Group × Outcome interaction, $F(1, 77) = 0.28, p > .05$. Examination of means in Table 6.9 indicates that, for both groups, mean response latency was faster following losses (1.13-s for PG group; 1.20-s for control group) than following wins (1.99-s for PG group; 1.98-s for control group), consistent with prediction. There was no significant main effect of Group, $F(1, 77) = 0.04, p > .05$.

*6.3.5.2.2 Slot machine simulation with low percentage payback rate*

ANOVA revealed a significant main effect of Outcome, $F(1, 77) = 101.10, p < .01$, and no significant Group × Outcome interaction, $F(1, 77) = 0.76, p > .05$. Examination of means in Table 6.9 indicates that, for both groups, mean response latency was faster following losses (0.81-s for PG group; 0.73-s for control group) than following wins (1.37-s for PG group; 1.40-s for control group), consistent with prediction. There was no significant main effect of Group, $F(1, 77) = 0.06, p > .05$.

**6.4 Discussion**

This study aimed to investigate inhibitory control and personality differences in pathological gamblers compared to non-problem gambling controls. Toward this end, the same four stop-signal tasks used in Experiments 2 and 3 of chapter 3 (sections 3.2 and 3.3, respectively) and in chapter 4 were used to assess group differences in inhibitory control across standard as well as modified versions of the stop-signal task, the Q-task (Newman et al., 1997) was used to assess group differences in inhibition (i.e., BIS functioning), the same two card perseveration (CP) tasks employed in chapter 5 were used to assess response perseveration (i.e., inhibitory control) on a 'Standard' as well as a 'Pause' version of this gambling related computerised behavioural task, the same two computerised slot machine simulations employed in chapter 5 were used to examine group differences in gambling related inhibitory control across slot machine simulations with high (70%) and low (30%) percentage payback rates, and the same six personality measures employed in chapters 4 and 5 (BIS/BAS Scales, SPSRQ, STAI Y2 scale, EPQ-RS, FSS, and PANAS) were used to assess group differences in self-reported sensitivity to reward/punishment (i.e., personality).

### *6.4.1 Personality*

At the time of writing the introduction to this thesis (chapter 1), no previous research had investigated explicit links between RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity and PG. Strong evidence had, however, related impulsivity (proposed to be linked to the BAS; see Corr, 2004) to PG (see chapter 1, section 1.3.1), leading to the suggestion in the present study that, within the context of RST, the disinhibited behaviour characterised by PG may result from hyper-sensitivity to reward. This prompted the prediction that pathological gamblers should be more highly BAS reactive than controls. Significant evidence was produced in support of this prediction; pathological gamblers scored higher than controls on the Sensitivity to Reward scale (BAS measure) of the SPSRQ. Thus, it could be suggested that the disinhibited behaviour characterised by PG may indeed result from a more reward sensitive personality. However, as well as being more highly BAS reactive than controls (as expected), significant (or near significant) evidence was also produced to suggest that pathological gamblers were more highly BIS/FFFS reactive than controls, contrary to prediction; pathological gamblers scored higher than controls on the Sensitivity to Punishment scale (BIS measure) of the SPSRQ, the STAI (BIS measure), and FSS Fear (FFFS measure). These findings suggest that pathological gamblers were hyper-sensitive to punishment (vs. controls), running contrary to evidence that problem gamblers continue to gamble due to *in*sensitivity to punishment (Vitaro et al., 1999).

Since writing the introduction, presented in chapter 1, a number of studies in the literature have investigated explicit links between RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity and problem gambling (e.g., Goudriaan, Oosterlaan, de Beurs, & van den Brink, 2006; Loxton, Nguyen, Casey, & Dawe, 2008). Consistent with the findings obtained in the present study, both Goudriaan et al. and Loxton et al. produced evidence showing that problem gamblers scored higher than normal controls on self-reported measures of both BIS and BAS activity. As previously discussed in chapter 5 (section 5.4.3), although highly BIS reactive individuals, when exposed to conflict, are likely to demonstrate inhibited behaviour in some situations, an approach response may also be initiated in an attempt to avoid punishment (Elliot & Thrash, 2002; McNaughton & Corr, 2004, 2008). According to revised RST, it is possible for the BIS to resolve a potential reward-punishment conflict situation (such as any gambling situation) by engaging the organism in an approach (rather than inhibited) response (McNaughton & Corr, 2004, 2008). Indeed, this was the stance adopted by Loxton et al. in explaining their findings that problem gamblers scored higher than normal controls on self-reported measures of BIS activity; it was suggested that, as a result of their anxious (i.e., high BIS/punishment sensitive) dispositions, 'problem gamblers may seek out the stimulation of gambling to avoid life stressors and facilitate psychological escape (Blaszczynski & Nower, 2002)' (p. 172).

The idea that pathological gamblers gamble to momentarily alleviate or escape from unpleasant feelings such as anxiety is not a new one, and since the findings of the present study, along with the other recent studies mentioned above (Goudriaan et al., 2006; Loxton et al., 2008), indicate that pathological gamblers might be highly anxious (as a group) personalities, this 'escapism' explanation seems highly plausible. However, recently, Corr (2009) and McNaughton and Corr (2009) have suggested a new and intriguing alternative explanation for the development and maintenance of maladaptive gambling behaviour; an explanation based upon the concept of 'relief of non-punishment'. One observation originally derived from a formal account of learning theory principles (see Gray, 1975) was that, within the broad two-dimensional affective model that characterises BIS theory, the omission of expected, or termination of, punishment is functionally equivalent to the presentation of rewarding stimuli, and thus serves as an adequate input to the BAS. Now, because the schedule of reinforcement in all forms of gambling activity generally involves a high ratio of punishment to reward, and because punishment is known to induce physiological arousal which energises and invigorates behaviour (Gray, 1987), this creates a situation in which the occurrence of a reward may have a super-charged input to the BAS due to the positive effects of relieving non-punishment (i.e., omission of an expected punishment; in this case, usual losses).

Corr (2009) and McNaughton and Corr (2009) suggest that relief of non-punishment is thus a powerful input to the BAS, which when coupled with punishment-induced physiological arousal, produces an emotional 'high' that produces rapid and resistant conditioning (e.g., to the paraphilia of the gambling context). These emotional 'highs' are *predicted* by the higher-density of punishments; and thus we start to get a clue to the paradoxical nature of pathological gambling: self-defeating strong BAS approach may be, somewhat paradoxically, maintained by punishment. The findings of the present study, along with the other recent studies mentioned above (Goudriaan et al., 2006; Loxton et al., 2008), indicate that pathological gamblers might be highly sensitive to punishment, and it is suggested here that this would make sense within the context of Corr's and McNaughton and Corr's explanation for the development and maintenance of maladaptive gambling behaviour. Greater sensitivity to punishment should theoretically lead to greater punishment-induced physiological arousal (evoked by the high ratio of punishment to reward in gambling situations) as well as greater relief of non-punishment (when a reward occurs) and thus a greater emotional 'high' that may become associated with gambling.

The results showed that, along with the group differences discussed above, EPQ-RS Neuroticism and Psychoticism scale scores also distinguished pathological gamblers from controls; pathological gamblers were found to score significantly higher than controls on both of these personality scales. Although not predicted in the present study (since the aim with regards to personality was to investigate explicit links between RST brain behavioural system activity and PG), these findings were consistent with those of previous research (e.g., Blaszczynski et al., 1986; Roy, Custer, Lorenz, & Linnoila, 1989) and so were not wholly unexpected. Blaszczynski et al. (1986) reported that, compared to the general population, pathological gamblers have higher Neuroticism and

Psychoticism scores, and Roy et al. (1989) produced similar findings in exclusively male samples (the PG group in the present study was predominantly composed of male participants).

*6.4.2 Stop-signal task performance*

No significant evidence was obtained in support of the prediction that pathological gamblers should demonstrate weaker inhibitory control across the four stop-signal tasks compared to controls. This prediction was based on growing evidence in the previous literature of the association between impaired inhibitory control and PG (see chapter 1, section 1.3.1), obtained using behavioural tasks such as the go/no-go task (Goudriaan et al., 2005) and the delayed response task (Dixon et al., 2003). Compared to these tasks, the stop-signal paradigm would be considered a 'purer' measure of the inhibitory control process (see chapter 1, section 1.3.1) and so the results obtained indicate strongly against an impaired inhibitory control in pathological gamblers. Despite the inconsistency of this finding in relation to the growing evidence in the previous literature, a recent study conducted by Rodriguez-Jimenez et al. (2006a) also produced results indicating against impaired inhibitory control in a group of pathological gamblers (using the Continuous Performance Test; CPT).

However, although the results of the present study suggest that there was no between-group difference in response inhibition across the four stop-signal tasks, significant evidence was produced indicating that the effect of the different task contingencies (i.e., specific motivational stimuli) on response inhibition differed when comparing the PG group with the control group. Previous research using the four stop-signal tasks (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that, compared to on the Baseline and Punishment tasks, due to the presence of specific rewarding stimuli resulting in an increased motivation on go-trials and, consequently, a decreased care in performance, participants had a weaker inhibitory control, faster mean reaction time (MRT) on go-trials, and poorer go-trial response accuracy on the Reward task. Based on the prediction that pathological gamblers should be hyper-sensitive to reward, it was predicted that these task effects should be stronger for pathological gamblers than for controls. In terms of inhibitory control, significant (or near significant) evidence was produced in support of this prediction; on the Reward task compared to on the Baseline and Punishment tasks, the PG group's probability of inhibition was found to decrease to a greater degree and their estimated time to inhibit a response (i.e., SSRT) slowed to a greater degree (i.e., the PG group's inhibitory control weakened to a greater degree) than the control group's.

In terms of response execution on the Reward task compared to on the Baseline and Punishment tasks, the only prediction for which significant evidence was produced in support of was that the PG group's go-trial response accuracy reduced to a greater degree than the control group's on the Reward task compared to on the Punishment task. The lack of significant evidence found in support of the other predictions indicates that the PG group's inhibitory control weakened to a greater degree than the control group's on the Reward task compared to on the Baseline and Punishment tasks without their ability to execute responses being effected to a greater degree than the control group's (except when comparing go-trial response accuracy on the Reward and Punishment tasks, as mentioned above).

Previous research using the four stop-signal tasks (chapter 3, sections 3.2 and 3.3; chapter 4) also demonstrated that, compared to on the Baseline task, due to the presence of specific punishing stimuli resulting in an increased care in performance, participants had a stronger inhibitory control and greater go-trial response accuracy on the Punishment task. Based on the prediction that pathological gamblers should be hypo-sensitive to punishment, it was predicted that these task effects should be weaker for pathological gamblers than for controls. However, contrary to prediction, these task effects were not found to be significantly different between the two groups but, also contrary to prediction, in terms of self-reported personality, the PG group was actually found to score higher than the control group on measures of BIS/FFFS activity. These findings concerning the PG group's self-reported personality indicate that, rather than being hypo-sensitive to punishment, pathological gamblers were more punishment sensitive than controls and this perhaps explains why the presence of specific punishing stimuli on the Punishment task had just as strong an effect on pathological gamblers' inhibitory control and go-trial response accuracy as it had on controls'.

In terms of Conflict task performance, previous research (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that, due to the presence of both specific rewarding and punishing stimuli resulting in an increased motivation on go-trials combined with an increased care not to make errors, participants had a weaker inhibitory control, faster MRT on go-trials, and poorer go-trial response accuracy on the Conflict task compared to on the Punishment task. Based on the predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was predicted that these task effects should be stronger for pathological gamblers than for controls. Significant evidence was produced in support of each of these predictions: on the Conflict task compared to on the Punishment task, the PG group's probability of inhibition was found to decrease to a greater degree (i.e., the PG group's inhibitory control weakened to a greater degree, based on this measure of response inhibition) than the control group's; on the Conflict task compared to on the Punishment task, the PG group's MRT on go-trials decreased to a greater degree than the control group's; and the number of response errors made on go-trials increased on the Conflict task compared to on the Punishment task to a greater degree for the PG group than for the control group. In terms of self-reported personality, the PG group were actually found to be hyper-sensitive to punishment as well as reward, indicating that these group differences in task effects did not result from hypo-sensitivity to punishment on the part of the PG group but from their hyper-sensitivity to the specific rewarding stimuli present on the Conflict task (which was absent on the Punishment task). The presence of the combination of both specific rewarding and punishing stimuli not only effected the PG group's inhibitory control to a greater degree (based on probability of inhibition as a measure of response inhibition) than the control group's but also their ability to execute responses on the Conflict task compared to on the Punishment task.

Previous research (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that participants had a stronger inhibitory control, slower MRT on go-trials, and greater go-trial response accuracy on the

Conflict task compared to on the Reward task. It was predicted that these task effects should be weaker for pathological gamblers than for controls. Significant evidence was produced in support of the prediction concerning MRT on go-trials; on the Conflict task compared to on the Reward task, the PG group's MRT on go-trials increased to a lesser degree than the control group's. However, contrary to prediction, the other measure of response execution, go-trial response accuracy, did not increase significantly differently for the two groups on the Conflict task compared to on the Reward task and, in terms of response inhibition, evidence was produced indicating that inhibitory control actually strengthened to a greater degree for the PG group than for the control group on the Conflict task compared to on the Reward task; pathological gamblers' estimated time to inhibit a response (i.e., SSRT) slowed to a greater degree than controls' on the Conflict task compared to on the Reward task. These unexpected findings might be explained by the fact that, also contrary to prediction, pathological gamblers were not found to be hypo-sensitive to punishment but, rather, they were in fact more punishment sensitive than controls in self-reported personality. Therefore, the evidence suggesting that pathological gamblers' inhibitory control strengthened to a greater degree than controls' on the Conflict task compared to on the Reward task was consistent with the finding that the PG group were hyper-sensitive to punishment, since the specific punishing stimuli present on the Conflict task (and absent on the Reward task) was intended to increase care in task performance (resulting in stronger inhibitory control).

Previous research (chapter 3, sections 3.2 and 3.3; chapter 4) has demonstrated that participants had a similar inhibitory control, faster MRT on go-trials, and similar go-trial response accuracy on the Conflict task compared to on the Baseline task. It was predicted that these task effects should be different for pathological gamblers compared to controls, in that, for pathological gamblers, on the Conflict task compared to on the Baseline task, inhibitory control should be weaker, MRT on go-trials should decrease to a greater degree (vs. controls' MRT on go-trials), and go-trial response accuracy should be poorer. In terms of response inhibition, based on probability of inhibition on stop-trials, near significant evidence was produced in support of this prediction: whereas probability of inhibition on stop-trials was similar on these two tasks for controls, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Conflict task than on the Baseline task for pathological gamblers. In terms of response execution, significant evidence was produced only in support of the prediction concerning go-trial response accuracy; whereas go-trial response accuracy was similar on the Conflict task compared to on the Baseline task for controls, the number of response errors made on go-trials was greater (i.e., go-trial response accuracy was poorer) on the Conflict task than on the Baseline task for pathological gamblers. Together, these findings indicate that the combination of both specific rewarding and punishing stimuli not only had a different effect on pathological gamblers' inhibitory control (based on probability of inhibition on stop-trials as a measure of response inhibition) than on controls' but also had a different effect on their ability to execute responses (based on go-trial response accuracy) on the Conflict task compared to on the Baseline task.

### *6.4.3 Q-task performance*

Newman et al. (1997) demonstrated using the Q-task that psychopaths (a clinical group characterised by disinhibited behaviour) displayed less inhibition than non-psychopathic controls on Q-present trials, consistent with weak BIS models of psychopathy (e.g., Fowles, 1980; Gray, 1987). No significant evidence was obtained in the present study to support the prediction that, similar to Newman et al.'s psychopaths, pathological gamblers should display less inhibition than controls on Q-present trials. In fact, although not significant, the PG group's mean Q-inhibition was slightly longer (i.e., indicating slightly greater inhibition on Q-present trials) than the control group's mean Q-inhibition. However, in terms of self-reported personality, the PG group was actually found to score higher than the control group on a couple of measures of BIS activity (the STAI and the Sensitivity to Punishment scale of the SPSRQ), also contrary to prediction but seemingly consistent with the unexpected results obtained on the Q-task; the task was designed as a measure of BIS activity and, although not significant, the group with the higher self-reported BIS activity (i.e., the PG group) demonstrated slightly greater inhibition on Q-present trials than the group with the lower self-reported BIS activity (i.e., the control group), thus almost providing support for the Q-tasks reputation as a face valid, behavioural assessment device for the measurement of BIS functioning (see Pickering et al., 1997).

Newman et al's (1997) findings concerning psychopaths' significantly different Q-inhibition to non-psychopathic controls' was limited to comparisons involving Anx+ (i.e., high BIS) participants. It is possible, therefore, that had the PG group and the control group been divided into Anx+ pathological gamblers and Anx+ controls, the between-group difference in mean Q-inhibition might have reached significance. This provides a possible avenue for future research into PG and inhibition on the Q-task. Nevertheless, the results obtained on the Q-task together with the self-report personality scale scores indicate that, contrary to prediction, rather than the PG group being less BIS reactive and thus demonstrating less inhibition than controls, the pathological gamblers were more highly BIS reactive and demonstrated no less inhibition than controls.

PG has been linked to 'behavioural disinhibition' (McCormick, 1993) but the results obtained in the present study suggest that pathological gamblers do not display disinhibited behaviour (vs. controls) unless specific rewarding stimuli is present. The Baseline and Punishment stop-signal tasks and the Q-task present participants with no specific rewarding stimuli whilst measuring inhibitory processes, and on these tasks mean differences in performance (although not significant) actually lean toward stronger inhibition on the part of the PG group (vs. the control group), possibly due to the PG group's significantly greater BIS activity. However, the introduction of specific rewarding stimuli on the Reward and Conflict stop-signal tasks had a greater effect on the PG group's inhibitory control than on the control group's (as discussed above in section 6.4.2); the PG group's task performance was shown to become disinhibited to a greater degree (vs. controls) on these tasks compared to on tasks with no specific rewarding stimuli (i.e., the Baseline and Punishment tasks). The results obtained on the CP tasks and the slot machine simulations (the gambling related computerised behavioural tasks), discussed in the following two sections, add support for the proposed link between PG and 'behavioural disinhibition' (McCormick) but again these tasks have specific rewarding stimuli present.

*6.4.4 Card perseveration (CP) task performance*

Consistent with Goudriaan et al.'s (2005) findings, significant evidence was produced in support of the prediction that pathological gamblers should perseverate longer (i.e., show weaker inhibitory control) than controls on the CP task; the PG group played a higher number of cards and won a smaller amount of cash than the control group on the standard task. However, evidence was also produced in support of the prediction that the forced 5-s pause imposed following response feedback on the 'Pause' task should reduce pathological gamblers' relative perseverative deficit; while the PG group were found to play a higher number of cards and win a smaller amount of cash than the control group on the standard task, these group differences were shown to be reduced on the CP task with forced pause.

Newman et al. (1987) compared psychopaths with non-psychopaths on different versions of the task and demonstrated that, while psychopaths perseverated to a greater degree than non-psychopaths on the standard task, psychopaths' relative perseverative deficit was reduced on a version of the task with a cumulative feedback display accompanied by a 5-s waiting period during which they were prevented from making another response. In accordance with these findings, the results obtained in the present study demonstrated that a forced 5-s pause following response feedback (immediate only, as opposed to the cumulative display used in Newman et al.'s study) effectively reduced pathological gamblers' relative perseverative deficit. This finding could have potentially valuable implications for informing practice in the treatment of PG. For example, gamblers in treatment could be instructed (or conditioned) to count to five and to check the amount of money they have remaining to gamble with following the outcome of every bet placed when involved in gambling behaviour, with the expectation that, as indicated by the results obtained on the CP task in the present study, this 5-s pause should result in greater attention to response feedback following each bet placed (i.e., whether it was a win or a loss, how much money was won/lost, and how much money remains to gamble with) and, thus, an earlier termination of gambling behaviour in the presence of unfavourable odds.

As expected, both the PG group and the control group played a lower number of cards and won a greater amount of cash (i.e., demonstrated lesser response perseveration) on the CP task with forced pause than on the standard task. These findings concerning the control group were consistent with previous research using the same two CP tasks (study presented in chapter 5), and were in accordance with Newman et al.'s (1987) findings for their control group of participants. Newman et al.'s control group played fewer cards and won more money on the task with a cumulative feedback display accompanied by a 5-s waiting period (during which they were prevented from making another response) than on the task with immediate feedback only (i.e., the standard task). Newman et al. 'reasoned that forcing subjects to pause after response feedback would improve their use of information about the changing probability of punishment and would reduce perseveration' (p. 146). The results obtained in the present study, consistent with those obtained in the study presented in chapter 5, demonstrated that perseveration was reduced through forcing participants to pause after response feedback even without the presence of a cumulative display of information about the changing probability of punishment.

As well as having potentially valuable implications for informing practice in the treatment of PG (discussed above), the findings of the present study could also be used to develop proposals for modifying the gambling environment in order to reduce the development of problematic gambling behaviour. For example, instead of gaming machines, such as slot machines and video poker simulations, being programmed to allow fast, continuous betting (as is currently the case with the majority of commercial gaming machines), they could be modified so that a forced 5-s pause (during which the player is prevented from placing another bet) is imposed following presentation of the outcome of each bet placed (i.e., response feedback). It is possible that such modifications to the gambling environment could, as demonstrated on the CP task in the present study and in the study presented in chapter 5, reduce maladaptive gambling behaviour and thus the development of gambling related problems.

Significant evidence was produced in support of the prediction that response latency should be faster following losses than following wins for both groups on the standard CP task. The results obtained also indicated that that this same effect was observed on the CP task with forced pause. These findings, concerning the control group, were consistent with previous research using the same two tasks (study presented in chapter 5), but contrary to Goudriaan et al.'s (2005) findings with their control group on a standard CP task; Goudriaan et al. demonstrated that their normal control group slowed down after losses, compared to after wins, on the CP task, whereas the PG group did not slow down after losses compared to after wins. It was on the basis of these findings that the following prediction was generated: response latency should be faster following losses than following wins for both groups on the standard task in the present study, but this effect should be stronger (i.e., response latency should speed-up following losses compared to following wins to a greater degree) for pathological gamblers than for controls. Although mean response latency following both outcomes (wins and losses) was found to be faster for the PG group than for the control group on the CP task with forced pause, the two groups did not differ significantly in the degree to which their response latencies' decreased following losses compared to following wins on either CP task, contrary to prediction. However, as discussed below, similar effects were observed on the two computerised slot machine simulations.

### *6.4.5 Slot machine simulation performance*

Consistent with previous research using the same two computerised slot machine simulations (study presented in chapter 5), significant evidence was produced in support of the prediction that a lower total number of credits should be bet on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. These findings indicate that the high rate of punishment on the simulation with low percentage payback rate resulted in more cautious gambling behaviour, in an attempt to minimise overall loss. The results run contrary to Weatherly and Brandt's (2004) finding that participants' gambling behaviour did not vary as a function of payback percentage. Whereas Weatherly and Brandt employed three different percentage payback values

(75%, 83% and 95%) on the slot machine simulations in their study, only two different values were employed in the present study (and in the study presented in chapter 5): (1) a high percentage payback rate of 70%; and (2) a low percentage payback rate of 30%. The results obtained provide further support for the suggestion made in chapter 5 that gambling behaviour on computerised slot machine simulations can vary as a function of percentage payback rate, so long as sufficiently varied rates are employed, and that perhaps the three different rates used in Weatherly and Brandt's study were simply not varied enough to produce significantly different gambling behaviour.

Also consistent with prediction, although, overall, a lower total number of credits were bet on the slot machine simulation with low percentage payback rate than on the simulation with high percentage payback rate, this simulation effect was shown to be weaker for the PG group than for the control group and, overall, the PG group were found to bet a higher total number of credits than the control group across the two simulations. The results indicate that, as expected, the PG group adopted a less cautious approach to gambling across the two slot machine simulations than the control group, and that exposure to the high rate of punishment on the simulation with low percentage payback rate was less effective in resulting in more cautious gambling behaviour, in an attempt to minimise overall loss, on this simulation compared to on the simulation with high percentage payback rate for the PG group than for the control group. This latter finding suggests that the PG group were perseverating for reward to a greater degree than the control group on the simulation with low percentage payback rate, similar to the way in which they performed the standard CP task (discussed above). As mentioned above (section 6.4.4), the results obtained concerning response perseveration on the two CP tasks have potential implications for reducing this type of maladaptive behaviour on other gambling tasks such as slot machines.

Like the CP task, performance of the two slot machine simulations exposed participants to a change in contingencies from highly rewarding (beginning of CP task/first simulation) to highly punishing (toward the end of the CP task/second simulation) except that this change was more gradual on the CP task (probability of initiating a rewarding trial was set at 90% for the first block of 10 trials and then decreased by 10% after every block of 10 trials thereafter until 100% of the final block of 10 trials were punishing) than across the two slot machines where contingencies suddenly changed from 70% rewarding trials on the first simulation to 70% punishing trials on the second. The optimum strategy to adopt on the CP task would be to exit after drawing approximately half of the cards, before the probability of losing becomes greater than the probability of winning, whereas because there was no option of exiting the slot machine simulation with low percentage payback rate, the optimum strategy on this simulation would be to minimise overall loss by placing minimum bets on the vast majority of trials. However, as discussed above, the PG group were found to play further through the standard CP task (i.e., perseverate to a greater degree) and, similarly, their gambling behaviour was less effected by exposure to the high rate of punishment on the simulation with low percentage payback rate (compared to on the simulation with high percentage payback rate) than the control group. Together, these findings indicate that pathological gamblers demonstrate greater perseveration (i.e., deficient inhibitory control) on gambling related tasks such as the CP task and slot machine simulations, than non-problem gambling controls, thus adding to growing evidence in the literature of the association between impaired inhibitory control and PG (see chapter 1, section 1.3.1).

Significant evidence was produced in support of predictions that response latency should be faster following losing trials than following winning trials on both slot machine simulations. These findings were in accordance with previous research using the same two simulations (study presented in chapter 5), other computerised (and real commercial) slot machines (Dixon & Schreiber, 2004; Schreiber & Dixon, 2001), and video poker simulations (Dixon & Schreiber, 2002). This contingency effect on response latency was observed in both groups, as predicted, with no significant group differences on or across outcome (i.e., contingency), similar to the results obtained on the standard CP task (discussed above). Significant evidence was also produced in support of the prediction that, based on the fact that the slot machine simulation with low percentage payback rate comprised the greatest number of losing trials, for both groups, overall response latency should be faster on the simulation with low percentage payback rate than on the simulation with high percentage payback rate. This finding was in accordance with previous research using the same two simulations (study presented in chapter 5). The results obtained for both groups on both simulations as well as on both CP tasks (discussed above) suggest that, consistent with the suggestions made in previous research (Dixon & Schreiber, 2002, 2004; Schreiber & Dixon, 2001; study presented in chapter 5), losing (i.e., punishing) trials result in faster initiation of the start of the consecutive trial (i.e., faster betting) than winning (i.e., rewarding) trials on computerised gambling tasks.

### *6.4.6 Implications, limitations and future directions*

In summary, results were obtained concerning PG and personality that have implications for understanding and explaining the development and maintenance of maladaptive gambling behaviour within the context of RST (see section 6.4.1). In addition, the behavioural tasks employed produced mixed support for the growing evidence in the literature of the association between impaired inhibitory control and PG. Altogether, the results obtained indicate that pathological gamblers did not demonstrate general inhibitory deficits (assessed by the standard stop-signal task and the Q-task; tasks which have not previously been utilised for the investigation of inhibitory control and PG), but that they were shown to demonstrate deficient inhibitory control (vs. controls) on tasks with specific rewarding contingencies. It seems that pathological gamblers were more influenced by, and perseverated to a greater degree for, specific rewarding stimuli (vs. controls) on the behavioural tasks when such stimuli was contingent. The findings obtained on the CP tasks have implications for reducing the apparent greater influence of (and thus the greater perseveration for) specific rewarding stimuli on pathological gamblers' behaviour, and thus these findings could have potentially valuable implications for informing practice in the treatment of PG as well as for the development of proposals for modifying the gambling environment in order to reduce the development of problematic gambling behaviour (discussed in section 6.4.4 above).

Several limitations of the present study warrant brief consideration here (a more in depth consideration of some of the limitations that apply to this study can be found in chapter 8, section

8.4). First, the use of gambling related tasks lacking monetary rewards/punishments limits the ecological validity of the results obtained in the same way as discussed in chapter 5, section 5.4.3. However, as in chapter 5, the tasks appear to have been effective in producing data supportive of predictions, but it would still be a good idea for future research (with sufficient financial resources; beyond the scope of the present study) to investigate pathological gamblers' performance on these tasks with real monetary contingencies to achieve greater ecological validity. Second, the use of a predominantly male pathological gambling sample, all of whom were recruited from a single betting shop (i.e., bookmakers) in Swansea, limits the generalisibility of the findings concerning PG, personality and inhibitory control beyond this gender and select gambling type. It is, therefore, recommended that future studies in this area of research should recruit pathological gamblers from a more diverse population and include more females. However, it would be important to subdivide such broad samples and assess any differences between subgroups since gender differences in PG and differences in the behaviour of gamblers that pursue different types of gambling have been documented in the previous literature (Raylu & Oei, 2002).

Third, the PG group were not screened for co-morbid disorders (e.g., alcohol or substance abuse or dependence, AD/HD, psychopathy, etc.) and so it could be argued that the effects observed might not have been due to the effects of PG but to the confounding effects of (potentially present) co-morbid disorders. However, had the PG group been carefully screened for any and all co-morbid disorders this would have further limited the generalisation of the results to a general PG population. Finally, psychometric measures of personality were used to compare self-reported sensitivity to reward/punishment (i.e., BIS/BAS/FFFS activity) in pathological gamblers vs. non-problem gambling controls. However, although mean scores on a number of these measures differentiated the PG group from the control group, direct associations between personality measures and performance on the behavioural tasks were not investigated. As such, the explanatory power of the influence of personality on differences in task performance was limited to assumptions based on significant group differences in personality scores. In order to understand the precise nature of the association between sensitivity to reward/punishment (i.e., BIS/BAS/FFFS activity) in pathological gamblers and inhibitory control on the various different behavioural tasks employed, future research should be directed at correlating these variables. However, it would be important for any such study to analyse the data in light of levels of reinforcement expectancies in relation to the tasks. The study presented in the following chapter highlights the importance of assessing levels of subjective reward/punishment in any study employing Gray's RST to investigate reactions to rewarding and punishing situations.

Chapter 7

# Experimental Study 6 (a Follow-up to Chapter 4): Reinforcement Expectancies and Associations between Self-reported Sensitivity to Reward/Punishment and Responses to Reward/Punishment on the Stop-signal Task

## 7.1 Aims and experimental predictions

### *7.1.1 Aims*

The study presented in chapter 4 produced a number of unexpected findings relating self-reported RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity to inhibitory control on the stop-signal task. This study, therefore, aimed to follow-up some of the unexpected findings by investigating one potential explanation for their presence: the idea that participants' reinforcement expectancies might influence associations between self-reported sensitivity to reward/punishment and actual responses to reward/punishment on the stop-signal task. Toward this end, the same four stop-signal tasks and personality measures (minus the FSS and the SOGS) used in the study presented in chapter 4 were employed in the present study.

In chapter 4, it was anticipated that, since, on the standard stop-signal task, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), higher self-reported BAS activity and Extraversion should be associated with weaker inhibitory control, and that these associations should be strongest on tasks with specific rewarding stimuli associated with speeded responses to the go-signal (i.e., on the Reward and Conflict tasks; described in chapter 2, section 2.1.1). Contrary to expectations, however, evidence was produced relating higher BAS activity and higher Extraversion to stronger inhibitory control on the Reward task and higher BAS activity to stronger inhibitory control on the Conflict task.

As discussed in chapter 4 (section 4.4.3), Corr (2001) has indicated the importance of assessing levels of subjective reward in any study employing Gray's RST to investigate reactions to rewarding and punishing situations to ensure that manipulations of motivation (in particular appetitive; see Corr 2002a) are effective. It is possible that putative appetitive tasks may elicit frustrative non-reward (aversive motivation) in certain participants who have high initial expectations of reward, leading to apparently theoretically inconsistent relationships between reactions to (assumed) rewarding situations and BAS activity. This idea, therefore, has the potential for explaining the unexpected findings concerning inhibitory control, BAS activity, and Extraversion presented in chapter 4; it is possible that, for some participants (i.e., high BAS participants and high Extraversion participants), the specific rewarding stimuli present on the Reward and Conflict tasks was not as rewarding as they had expected, resulting in frustrative non-reward leading to avoidance of the frustrating stimuli (i.e., the specific rewarding stimuli present on go-trials) and, thus, stronger inhibitory control on these tasks.

It has been argued that 'participant-perceived reward needs to be equal to or greater than expected levels of reward for appetitive manipulations to be considered effective and for positive relationships between BAS traits and actual reactions to reward to be observed' (Kambouropoulos & Staiger, 2004, p. 1155). Levels of subjective reward were not directly measured in the study presented in chapter 4 and, indeed, little exists in the previous literature investigating reward expectancies and actual perceived reward. Kambouropoulos and Staiger assessed levels of reinforcement expectancies in relation to two behavioural tasks, assumed to tap into BIS/BAS functioning, using two 10-cm visual analogue scales. One scale was administered immediately prior to task performance and provided a measure of expected reward (i.e., "how rewarding do you expect the task to be?") and the second was administered immediately following task completion assessing actual perceived reward (i.e., "how rewarding did you find the task?"). For the purposes of Kambouropoulos and Staiger's study, a difference score was calculated as: actual perceived reward minus expected reward. The authors produced a pattern of results indicating that:

> If participants perceive a presumed appetitive task as less rewarding than initially expected, theoretically inconsistent associations between self-report measures of BIS/BAS and actual responses to reward will most likely be observed. In contrast, when . . . [a presumed appetitive task] was perceived to be rewarding, thereby representing an adequate input to the BAS, more theoretically consistent relationships between reward responsivity and self-report BIS/BAS measures were found. (Kambouropoulos & Staiger, p. 1163)

It was anticipated that by employing a similar method to that used by Kambouropoulos and Staiger (2004) for assessing levels of reinforcement expectancies in relation to the stop-signal tasks (assumed to tap into BIS/BAS functioning), the unexpected findings concerning inhibitory control, BAS activity, and Extraversion presented in chapter 4 could be further investigated and perhaps explained.

*7.1.2 Experimental predictions*

A number of predictions were generated based on the assumption that 'participant-perceived reward needs to be equal to or greater than expected levels of reward for appetitive manipulations to be considered effective and for positive relationships between BAS traits and actual reactions to reward to be observed' (Kambouropoulos & Staiger, 2004, p. 1155). It was predicted that higher self-reported BAS activity (i.e., scores on the Sensitivity to Reward scale of the SPSRQ, and the BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales) and Extraversion (E) should be most strongly associated with weaker inhibitory control (compared to on the Baseline and Punishment tasks) on the Reward and Conflict tasks (consistent with predictions outlined in chapter 4; see section 4.1.2 for rationale) among participants that perceive these tasks to be as or more rewarding than initially expected.

Conversely, it was predicted that higher self-reported scores on these same personality measures should be most strongly associated with stronger inhibitory control (compared to on the Baseline and Punishment tasks) on the Reward and Conflict tasks (i.e., theoretically inconsistent associations between self-report measures of BAS/Extraversion and actual responses to rewarding stimuli present on these tasks should be observed; consistent with some of the unexpected findings presented in chapter 4) among participants that perceive these tasks to be less rewarding than initially expected.

## 7.2 Method

### *7.2.1 Participants*

Twenty-six undergraduate students (15 males, 11 females), studying psychology at Swansea University, participated. Participants' ages ranged between 19 and 23 years (mean = 20.80, S.D. = 0.90). They were recruited by means of volunteer or self-selected sampling methods using a subject pool credit website, and gave their written informed consent to take part in the experiment after they had been assured of the anonymity of their results. All had to be able to read and understand English as well as follow procedure and were awarded course credits for their participation.

### *7.2.2 Materials and design*

#### *7.2.2.1 Personality measures*

Each of the personality measures employed (BIS/BAS Scales, SPSRQ, EPQ-RS, STAI Y2 scale, and PANAS) are described in detail in chapter 2, section 2.2. The order of the personality measures was kept the same across all participants. Each participant completed them in the following, consecutive, order: (1) STAI; (2) EPQ-RS; (3) BIS/BAS Scales; (4) SPSRQ; and (5) PANAS.

*7.2.2.1.1 Descriptive statistics*

Means, standard deviations and correlations between personality measures are shown in Table 7.1. These data were similar to those reported in previous psychometric studies with larger samples (Jorm et al. 1999; Perkins et al., 2007; Torrubia et al., 2001). However, there were inconsistencies among correlations between BAS and Extraversion measures. The only two BAS measures shown to be significantly positively correlated with one another, as expected, were the BAS Drive and BAS Fun Seeking scales of the BIS/BAS Scales, $r(26) = .54$, $p < .01$. Although correlations between other BAS measures did not reach significance, $p > .05$, importantly, examination of Table 7.1 reveals that these correlations were generally shown to be in the expected, positive, direction (except for some correlations involving the BAS Reward Responsiveness scale of the BIS/BAS Scales).

*7.2.2.2 Stop-signal tasks*

The four stop-signal tasks (Baseline, Punishment, Reward, and Conflict) were the same as those used in chapter 4 and are described in detail in chapter 2, section 2.1.1. The written Baseline, Punishment, Reward, and Conflict task instructions given to participants are shown in full in Appendices A, E, F, and G, respectively. The order of stop-signal task administration was the same as in chapter 4 (see section 4.2.3).

*7.2.2.3 Visual analogue scales for assessment of levels of reinforcement expectancies*

Two 10-cm visual analogue scales were employed to assess levels of reinforcement expectancies in relation to the four stop-signal tasks (see Figure 7.1). The first provided a measure of expected reward (i.e., "how rewarding do you expect the task to be?"). The second assessed actual perceived reward (i.e., "how rewarding did you find the task?"). As in Kambouropoulos and Staiger's (2004) study, a difference score was calculated in the present study as: actual perceived reward minus expected reward. Each of the two scales used to assess levels of reinforcement expectancies in relation to the Baseline task, the Punishment task, and the Conflict task (Figure 7.1 shows the two scales used in conjunction with the Reward task) are shown in Appendix M.

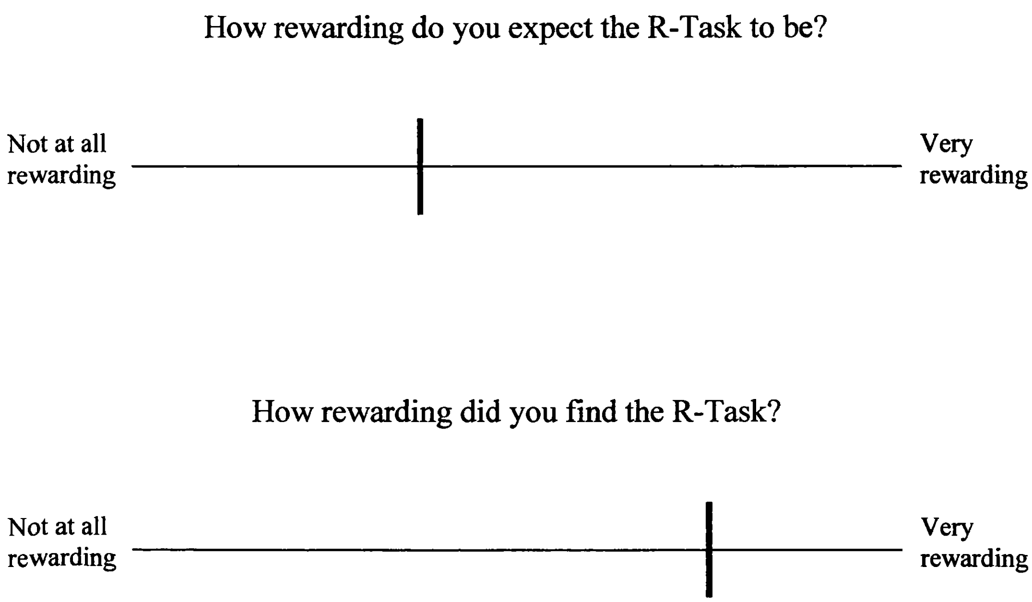


*Figure 7.1.* The two visual analogue scales employed to assess levels of reinforcement expectancies in relation to the Reward stop-signal task (R-Task). The vertical red lines have been added to exemplify typical responses: in this case, the participant perceived the Reward task to be more rewarding than initially expected.

### *7.2.3 Procedure*

On arrival at the laboratory the participant was seated and instructed to read the information sheet (the details of which are outlined below) and to ask for a consent form when finished if they wished to continue. The information sheet informed the participant that the present study involved completing a number of personality tests in the form of questionnaires and performing a series of tasks presented on a computer. It also explained how written instructions of how to complete each individual questionnaire and perform each computer task would be provided. The information sheet assured the participant that they were free to withdraw from the study at any point without penalty, that they could request a break at any time, that all results would be anonymised and that it would not be possible to identify individual participant's data. If the participant wished to continue having read the information sheet they were instructed to complete the written consent form. The completed consent form was kept separately from all other data in order to ensure the confidentiality and anonymity of the participant's results.

Having obtained informed consent, the personality questionnaires described in the materials and design section above (section 7.2.2.1) were administered to the participant in the order described in this same section. The participant was instructed to follow the written instructions provided at the beginning of each individual questionnaire and to complete them as quickly as possible. On completion of the questionnaires, the four computer based stop-signal tasks described in the materials and design section above (section 7.2.2.2) were administered to the participant in the order described in this same section. The participant was instructed to follow the written instructions provided at the beginning of each computer task. The participant was always administered the appropriate pre-test measure of expected reward (the first of the visual analogue scales described in section 7.2.2.3) to complete immediately prior to task performance, before each task, following administration of the written task instructions. The appropriate post-test measure of actual perceived reward (the second of the visual analogue scales described in section 7.2.2.3) was administered to the participant always immediately on completion of each task, also then followed by the administration of a PANAS.

Participants were debriefed on completion of the final PANAS following completion of the final stop-signal task (the Conflict task), and thanked for their participation. The participant was again assured that all the information they provided would remain confidential to the study and that the information they provided would be used to investigate personality and inhibitory control on the stop-signal task in the presence of reward and punishment. The data collected and saved from each of the four stop-signal tasks for each of the ten participants had to be individually analysed and recorded in spreadsheets.

Table 7.1

*Means, Standard Deviations and Correlations between Personality Measures*

| | BD | BFS | BRR | BIS | SP | SR | P | E | N | L | STAI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BD | — | | | | | | | | | | |
| BFS | .48* | — | | | | | | | | | |
| BRR | .35 | .54** | — | | | | | | | | |
| BIS | -.12 | -.24 | .10 | — | | | | | | | |
| SP | .04 | -.33 | -.03 | .78** | — | | | | | | |
| SR | .19 | .03 | -.15 | -.28 | -.03 | — | | | | | |
| P | .05 | .51** | .07 | -.63** | -.56** | .30 | — | | | | |
| E | .19 | .30 | -.24 | -.76** | -.52** | .26 | .50* | — | | | |
| N | -.13 | -.23 | -.18 | .68** | .63** | -.12 | -.39 | -.38 | — | | |
| L | -.12 | -.23 | -.06 | .12 | .03 | -.54** | -.31 | -.18 | -.27 | — | |
| STAI | -.17 | -.27 | -.22 | .73** | .76** | -.25 | -.45* | -.42* | .78** | -.01 | — |
| Mean | 10.35 | 11.69 | 16.00 | 19.92 | 8.96 | 12.46 | 4.08 | 7.08 | 4.50 | 3.00 | 40.42 |
| SD | 2.12 | 2.77 | 3.12 | 4.53 | 5.22 | 4.54 | 2.31 | 2.97 | 3.13 | 1.83 | 9.68 |

*Note.* n = 26; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SR = Sensitivity to Reward; SP = Sensitivity to Punishment;

P = Psychoticism; E = Extraversion; N = Neuroticism; L = Lie; STAI = Speilberger Trait Anxiety Inventory.

**p* < .05. ***p* < .01.

*7.2.4 Dependent measures and data analyses of stop-signal task performance*

*7.2.4.1 Dependent measures of stop-signal task performance*

See chapter 2, section 2.1.1.5.1, for detailed descriptions of dependent measures of response inhibition (probability of inhibition on stop-trials and stop-signal reaction time) and methods for assessing these dependent measures for each participant on each task.

*7.2.4.2 Data analyses of stop-signal task performance*

*7.2.4.2.1 Reinforcement expectancies and associations between personality and response inhibition*

Associations between response inhibition and personality on the Reward task were analysed separately for the two groups with different perceived vs. expected reward (as or more rewarding than initially expected or less rewarding than initially expected) in relation to the Reward task. Associations between response inhibition and personality on the Conflict task were analysed separately for the two groups with different perceived vs. expected reward (as or more rewarding than initially expected or less rewarding than initially expected) in relation to the Conflict task. Pearson correlations were calculated between the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT) for all four tasks, on the one hand, and BAS measures (BAS Drive, BAS Fun-seeking, BAS Reward Responsiveness, and SR) and Extraversion (E) on the other hand. Pearson correlations were also calculated between the four dependent measures of task performance for all four tasks, on the one hand, and Lie scale score, age, and sex (with male coded as 1 and female coded as 2), on the other hand, in order to investigate any associations between Lie scale score, age, sex, and stop-signal task performance.

*7.2.4.2.2 Reinforcement expectancies and task differences on associations between personality and response inhibition*

The combination of the categorical variable Task and the continuous variable Personality as predictors of the two dependent measures of response inhibition (probability of inhibition on stop-trials and SSRT), was analysed separately for the two groups with different perceived vs. expected reward (as or more rewarding than initially expected or less rewarding than initially expected) in relation to the Reward task and for the two groups with different perceived vs. expected reward (as or more rewarding than initially expected or less rewarding than initially expected) in relation to the Conflict task by separate one-way repeated measure analyses of covariance (ANCOVA) with Task (Baseline, Punishment, Reward, and Conflict) as the within-subjects factor. Covariates were the subscales of the BIS/BAS Scales (BAS Drive, BAS Fun Seeking, BAS Reward Responsiveness, and BIS; in a single ANCOVA), subscales of the SPSRQ (SP and SR; in a single ANCOVA), and subscales of the EPQ-RS (P, E, N, and L; in a single ANCOVA). Predictions were tested using simple within-subjects contrasts with either the Reward task selected as the reference category (for analyses involving perceived vs. expected reward in relation to the Reward task) or the Conflict task selected as the reference category (for analyses involving perceived vs. expected reward in relation to the Conflict task).

## 7.3 Results

Preliminary analyses identified one case, in the group that perceived the Reward task to be as or more rewarding than initially expected and in the group that perceived the Conflict task to be as or more rewarding than initially expected, with a probability of inhibition score of 0.00 on the Baseline task. This case was removed from analysis since the probability of inhibition score of 0.00 means the participant demonstrated failure to inhibit responses to go-stimuli on all stop-trials, making it impossible to calculate SSRT, and, most probably, this reflects a misunderstanding of the task requirements. Another case, in these same two groups, with an extremely high z score (beyond the

$p = .001$ criterion of 3.29, two-tailed) on go-trial response accuracy on the Baseline task was found to be a univariate outlier. The outlier was deleted, leaving 24 cases for analyses: 14 in the group that perceived the Reward task to be as or more rewarding than initially expected, 10 in the group that perceived the Reward task to be less rewarding than initially expected; 13 in the group that perceived the Conflict task to be as or more rewarding than initially expected, 11 in the group that perceived the Conflict task to be less rewarding than initially expected.

*7.3.1 Reinforcement expectancies and associations between personality and response inhibition*

Table 7.2 shows correlations between the dependent measures of response inhibition on the four stop-signal tasks and BAS/Extraversion measures (as well as Lie), age, and sex for each of the four different groups. There were no significant associations between Lie scale score, age, or sex and the two dependent measures of response inhibition on any of the four tasks for any group, $p > .05$.

*7.3.1.1 Group that perceived the Reward task to be as or more rewarding than initially expected*

Examination of Table 7.2 shows that, as expected, significant correlations were obtained for measures of response inhibition on the Reward stop-signal task and a measure of BAS activity. Consistent with prediction, a higher score on the BAS Fun Seeking scale was related to a lower probability of inhibition on stop-trials, $r(14) = -.85$, $p < .01$, and a slower SSRT, $r(14) = .67$, $p < .01$, (i.e., weaker inhibitory control) on the Reward task. Also consistent with prediction, a higher score on the BAS Drive scale was near significantly related to a lower probability of inhibition on stop-trials on the Reward task, $r(14) = -.52$, $p = .06$.

Table 7.2

*Correlations between Measures of Response Inhibition on the Four Stop-signal Tasks and BAS/Extraversion (as well as Lie) Measures, Age, and Sex for the Different Groups*

| Task | Measure | BD | BFS | BRR | SR | E | L | Age | Sex |
|---|---|---|---|---|---|---|---|---|---|
| Group that Perceived Reward Task to be as or More Rewarding than Initially Expected (n = 14) | | | | | | | | | |
| Baseline | *P* (In) | -.59* | -.43 | -.12 | -.19 | -.20 | -.13 | .09 | -.23 |
| | SSRT | .48 | .50 | -.25 | .12 | .41 | -.17 | -.06 | .04 |
| Punishment | *P* (In) | -.02 | -.63* | -.51 | -.50 | -.12 | -.05 | .27 | -.09 |
| | SSRT | .36 | -.26 | .21 | -.02 | -.15 | .28 | -.30 | .05 |
| Reward | *P* (In) | -.52 | -.85** | -.13 | -.19 | -.11 | .08 | .25 | -.03 |
| | SSRT | .11 | .67** | -.10 | .06 | .21 | -.47 | .21 | .29 |
| Conflict | *P* (In) | -.56* | -.55* | -.34 | -.18 | -.31 | -.11 | .09 | -.01 |
| | SSRT | -.16 | .52 | -.38 | -.21 | .75** | .04 | .17 | -.06 |
| Group that Perceived Reward Task to be Less Rewarding than Initially Expected (n = 10) | | | | | | | | | |
| Baseline | *P* (In) | -.01 | -.31 | -.69* | .35 | .31 | -.06 | .20 | .43 |
| | SSRT | .08 | -.25 | -.52 | .26 | .36 | -.20 | -.10 | .23 |
| Punishment | *P* (In) | .03 | .00 | -.25 | .17 | .13 | -.10 | .31 | .06 |
| | SSRT | .52 | .27 | .28 | -.40 | -.01 | .28 | -.30 | -.13 |
| Reward | *P* (In) | .62 | .33 | -.11 | .23 | .51 | -.40 | .16 | -.13 |
| | SSRT | -.88** | -.69* | -.30 | .00 | -.60 | .13 | -.28 | .14 |
| Conflict | *P* (In) | .22 | -.01 | -.47 | .53 | .41 | -.56 | .02 | .11 |
| | SSRT | -.64* | -.54 | -.58 | .41 | .04 | -.05 | -.03 | .52 |
| Group that Perceived Conflict Task to be as or More Rewarding than Initially Expected (n = 13) | | | | | | | | | |
| Baseline | *P* (In) | -.59* | -.42 | -.35 | -.06 | .00 | -.15 | .17 | -.14 |
| | SSRT | .21 | .11 | -.36 | .14 | .19 | .05 | -.26 | .18 |
| Punishment | *P* (In) | -.52 | -.36 | -.29 | -.22 | -.16 | -.05 | .30 | -.03 |
| | SSRT | .42 | .22 | .25 | -.11 | .14 | .51 | -.27 | .05 |
| Reward | *P* (In) | -.41 | -.38 | .00 | -.38 | -.26 | .10 | .25 | .03 |
| | SSRT | -.15 | .07 | -.19 | .24 | .05 | -.52 | .10 | .32 |
| Conflict | *P* (In) | -.65* | -.53 | -.34 | -.22 | -.22 | -.13 | .16 | -.02 |
| | SSRT | -.36 | -.02 | -.63* | .28 | .46 | -.30 | .04 | .27 |
| Group that Perceived Conflict Task to be Less Rewarding than Initially Expected (n = 11) | | | | | | | | | |
| Baseline | *P* (In) | -.12 | -.15 | -.34 | -.05 | .16 | -.01 | .02 | .17 |
| | SSRT | .74** | -.01 | -.08 | .34 | .25 | -.50 | .17 | -.01 |
| Punishment | *P* (In) | .01 | .23 | -.34 | .14 | .34 | -.18 | .23 | -.01 |
| | SSRT | -.04 | -.60* | -.36 | -.28 | .02 | -.08 | .16 | -.24 |
| Reward | *P* (In) | .45 | .22 | -.20 | .41 | .72* | -.46 | .16 | -.22 |
| | SSRT | -.27 | -.30 | .06 | -.32 | -.82** | .17 | -.14 | .05 |
| Conflict | *P* (In) | .40 | .24 | -.40 | .47 | .43 | -.56 | -.10 | .12 |
| | SSRT | -.24 | -.43 | .03 | -.33 | -.01 | .54 | .23 | .02 |

*Note.* *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time; BD = BAS Drive; BFS = BAS Fun Seeking; BRR = BAS Reward Responsiveness; SR = Sensitivity to Reward; E = Extraversion; L = Lie.

*$p < .05$. **$p < .01$.

Significant correlations were also obtained for measures of response inhibition on the other three tasks and measures of BAS activity. A higher score on the BAS Drive scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Baseline task, $r(14) = -.59$, $p < .05$, and on the Conflict task, $r(14) = -.56$, $p < .05$, and a higher score on the BAS Fun Seeking scale was related to a lower probability of inhibition on stop-trials on the Punishment task, $r(14) = -.63$, $p < .05$, and on the Conflict task, $r(14) = -.55$, $p < .05$.

Contrary to prediction, Extraversion was not significantly related to either of the two measures of response inhibition on the Reward task, $p < .05$. However, a higher Extraversion score was significantly related to a slower SSRT (i.e., weaker inhibitory control) on the Conflict task, $r(14) = .75$, $p < .01$.

*7.3.1.2 Group that perceived the Reward task to be less rewarding than initially expected*

Examination of Table 7.2 shows that, as expected, significant correlations were obtained for a measure of response inhibition on the Reward stop-signal task and measures of BAS activity. Consistent with prediction, higher scores on the BAS Drive and BAS Fun Seeking scales were related to a faster SSRT (i.e., stronger inhibitory control) on the Reward task, $r(10) = -.88$, $p < .01$, and, $r(10) = -.69$, $p < .05$, respectively. A higher score on the BAS Drive scale was also near significantly related to the other measure of response inhibition, probability of inhibition on stop-trials, on the Reward task, $r(10) = .62$, $p = .06$. The positive sign of this correlation reflects the fact that a higher BAS Drive score was associated with a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on this task, again consistent with prediction.

Significant correlations were also obtained for measures of response inhibition on the Baseline and Conflict tasks and measures of BAS activity. A higher score on the BAS Reward Responsiveness scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Baseline task, $r(10) = -.69$, $p < .05$, and a higher score on the BAS Drive scale was related to a faster SSRT (i.e., stronger inhibitory control) on the Conflict task, $r(10) = -.64$, $p < .05$.

A higher Extraversion score was near significantly related to a faster SSRT on the Reward task, $r(10) = -.60$, $p = .07$, consistent with prediction.

*7.3.1.3 Group that perceived the Conflict task to be as or more rewarding than initially expected*

Examination of Table 7.2 shows that, as expected, significant correlations were obtained for measures of response inhibition on the Conflict stop-signal task and measures of BAS activity. Consistent with prediction, a higher score on the BAS Drive scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Conflict task, $r(13) = -.65$, $p < .05$. However, a higher score on the BAS Reward Responsiveness scale was related to a faster SSRT (i.e., stronger inhibitory control) on the Conflict task, $r(13) = -.63$, $p < .05$, contrary to prediction. A higher score on the BAS Fun Seeking scale was near significantly related to a lower probability of inhibition on stop-trials on the Conflict task, $r(13) = -.53$, $p = .06$, consistent with prediction.

A significant correlation was also obtained for a measure of response inhibition on the Baseline task and a measure of BAS activity. A higher score on the BAS Drive scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Baseline task, $r(13) = -.59$, $p < .05$. Contrary to prediction, Extraversion was not significantly related to either of the two measures of response inhibition on the Conflict task, $p < .05$.

*7.3.1.4 Group that perceived the Conflict task to be less rewarding than initially expected*

Examination of Table 7.2 shows that, contrary to prediction, no measure of BAS activity (Sensitivity to Reward scale of the SPSRQ, BAS Drive, BAS Fun Seeking, and BAS Reward Responsiveness scales of the BIS/BAS Scales) or Extraversion was significantly related to the two measures of response inhibition on the Conflict task, $p < .05$.

Significant correlations were obtained for measures of response inhibition on the other three tasks and measures of BAS activity. A higher score on the BAS Drive scale was related to a slower SSRT (i.e., weaker inhibitory control) on the Baseline task, $r(11) = .74$, $p < .01$, a higher score on the BAS Fun Seeking scale was related to a faster SSRT on the Punishment task, $r(11) = -.60$, $p < .05$, and a higher Extraversion score was related to a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control), $r(11) = .72$, $p < .05$, and a faster SSRT, $r(11) = -.82$, $p < .01$, on the Reward task.

*7.3.2 Reinforcement expectancies and task differences on associations between personality and response inhibition*

*7.3.2.1 BIS/BAS Scales*

*7.3.2.1.1 Group that perceived the Reward task to be as or more rewarding than initially expected*

The results of the simple within-subjects contrasts are summarised in Table 7.3. Examination of Table 7.3 shows that, for probability of inhibition on stop-trials, there was a significant interaction between Task and BAS Fun Seeking when comparing the Reward task with the Baseline task, $F(1, 9) = 5.84$, $p < .05$, and a near significant interaction between Task and BAS Fun Seeking when comparing the Reward task with the Punishment task, $F(1, 9) = 4.78$, $p = .06$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) differed according to Task when comparing the Reward task with the Baseline task and when comparing the Reward task with the Punishment task. Figure 7.2 displays the correlation between probability of inhibition on stop-trials and BAS Fun Seeking on the Baseline, Punishment, and Reward tasks. The regression lines in panels R, P and B of Figure 7.2 indicate that, consistent with prediction, while a higher score on the BAS Fun Seeking scale was related to a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Reward task, $p < .01$, this same association on the Punishment task, $p = .06$, was comparatively weaker and, in general, there was only a moderate trend toward this same association on the Baseline task.

Table 7.3

*Summary of Simple Within-subjects Contrasts, for the Group that Perceived the Reward Task to be as or More Rewarding than Initially Expected, Showing Interaction Effects between Task and BAS Measures of the BIS/BAS Scales when Comparing the Reward Task with the Baseline and Punishment Tasks for Measures of Response Inhibition*

| Source | Measure | Task | df | *F* | *p* |
|---|---|---|---|---|---|
| Task × BAS Drive | *P* (In) | Reward vs. Baseline | 1 | 2.21 | .17 |
| | | Reward vs. Punishment | 1 | 0.03 | .88 |
| | SSRT | Reward vs. Baseline | 1 | 2.30 | .16 |
| | | Reward vs. Punishment | 1 | 1.06 | .33 |
| Error | | | 9 | | |
| Task × BAS Fun Seeking | *P* (In) | Reward vs. Baseline | 1 | 5.84* | .04 |
| | | Reward vs. Punishment | 1 | 4.78 | .06 |
| | SSRT | Reward vs. Baseline | 1 | 3.08 | .11 |
| | | Reward vs. Punishment | 1 | 5.82* | .04 |
| Error | | | 9 | | |
| Task × BAS Reward Responsiveness | *P* (In) | Reward vs. Baseline | 1 | 1.57 | .24 |
| | | Reward vs. Punishment | 1 | 0.16 | .70 |
| | SSRT | Reward vs. Baseline | 1 | 1.26 | .29 |
| | | Reward vs. Punishment | 1 | 0.15 | .70 |
| Error | | | 9 | | |

*Note.* n = 14; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time.

*$p < .05$.

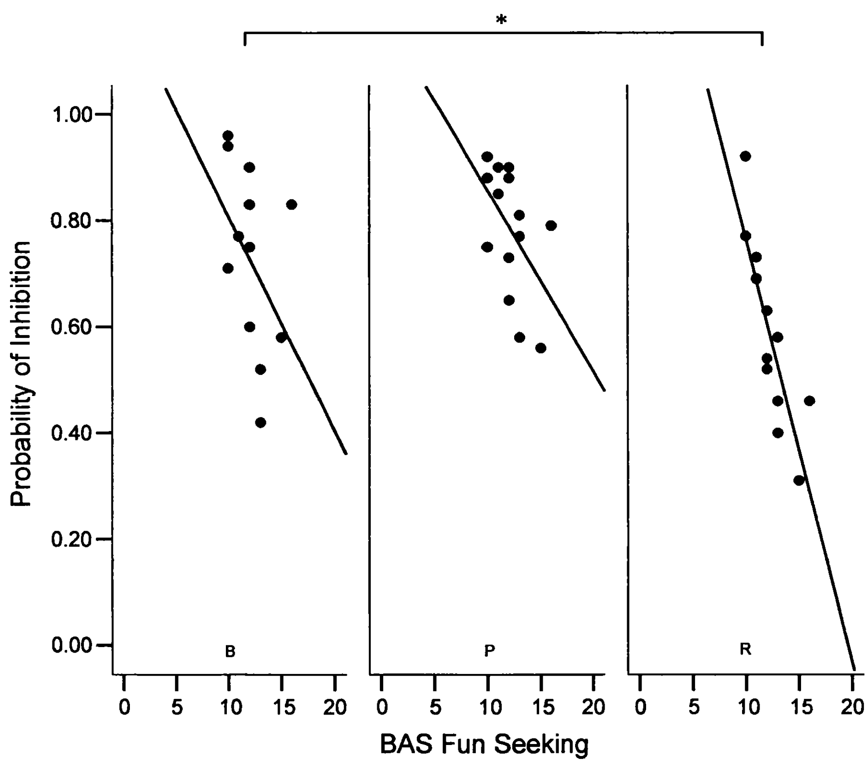


*Figure 7.2.* BAS Fun Seeking scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be as or more rewarding than initially expected (n = 14).

*$p < .05$.

For the other measure of response inhibition, SSRT, there was a significant interaction between Task and BAS Fun Seeking when comparing the Reward task with the Punishment task, $F(1, 9) = 5.82$, $p < .05$. This suggests that, as expected, the response of SSRT to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 7.3 displays the correlation between SSRT and BAS Fun Seeking on the Baseline, Punishment, and Reward tasks. The regression lines in panels R and P of Figure 7.3 indicate that, consistent with prediction, a higher score on the BAS Fun Seeking scale was more strongly associated with a slower SSRT (i.e., weaker inhibitory control) on the Reward task than on the Punishment task (in fact, in general, there was a slight trend toward the opposite association on the Punishment task). Contrary to prediction, no

Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction was significant when comparing the Reward task with the Baseline task for SSRT, $p > .05$.

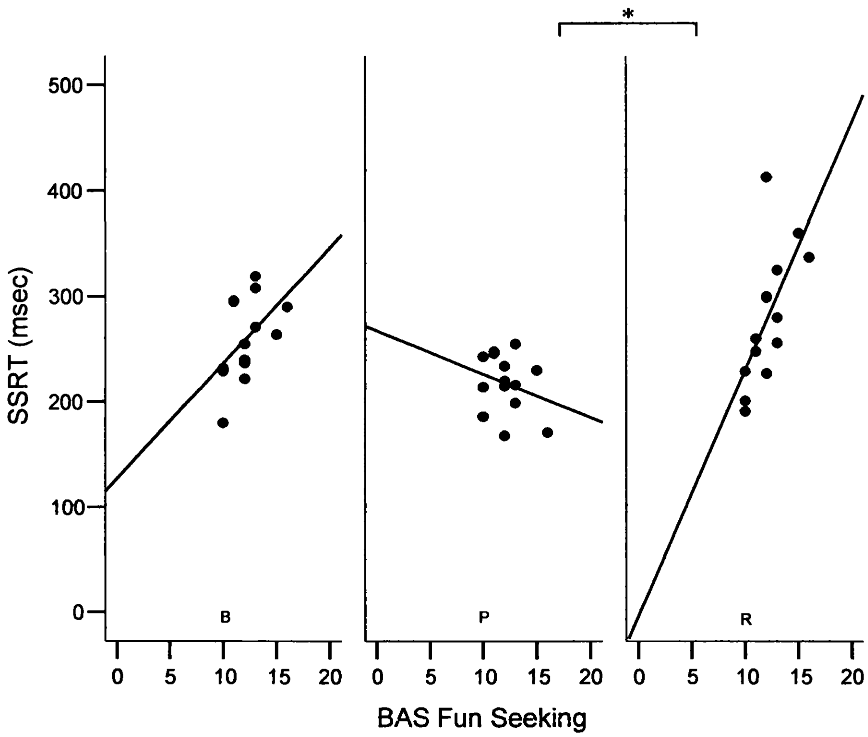


*Figure 7.3.* BAS Fun Seeking scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be as or more rewarding than initially expected (n = 14).

$^*p < .05$.

*7.3.2.1.2 Group that perceived the Reward task to be less rewarding than initially expected*

The results of the simple within-subjects contrasts are summarised in Table 7.4. Examination of Table 7.4 shows that, for probability of inhibition on stop-trials, there was a significant interaction between Task and BAS Drive when comparing the Reward task with the Punishment task, $F(1, 5) = 7.68, p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 7.4 displays the correlation between probability of inhibition on stop-trials and BAS

Drive on the Baseline, Punishment, and Reward tasks. The regression lines in panels R and P of Figure 7.4 indicate that, consistent with prediction, a higher score on the BAS Drive scale was more strongly associated with a higher probability of inhibition (i.e., stronger inhibitory control) on the Reward task than on the Punishment task (in fact, in general, there was no apparent trend toward an association between BAS Drive score and probability of inhibition on stop-trials on the Punishment task).

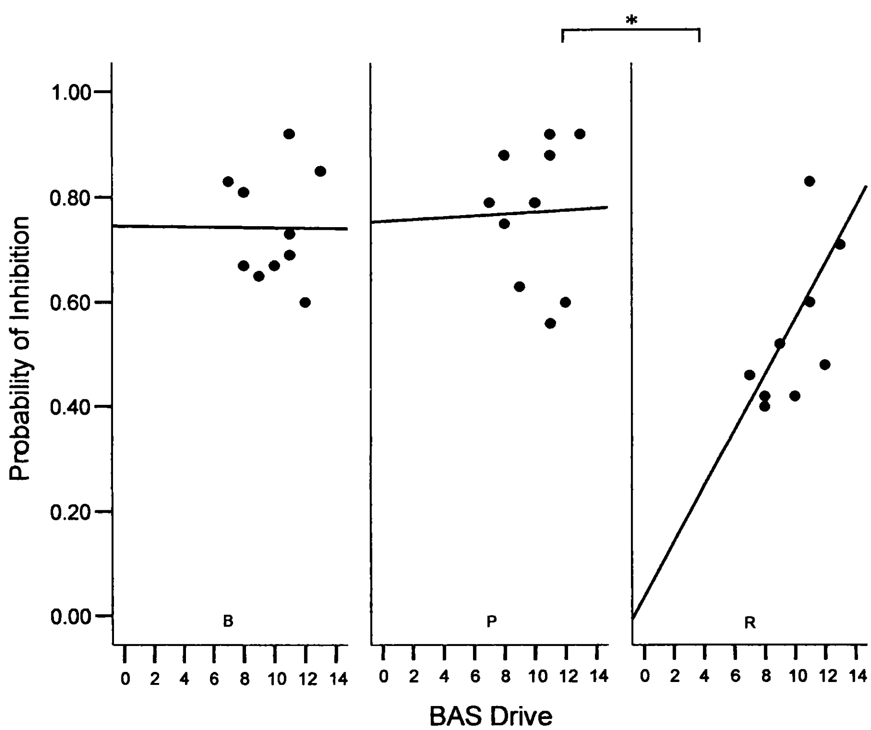


*Figure 7.4.* BAS Drive scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be less rewarding than initially expected (n = 10).

*$p < .05$.

Table 7.4

*Summary of Simple Within-subjects Contrasts, for the Group that Perceived the Reward Task to be Less Rewarding than Initially Expected, Showing Interaction Effects between Task and BAS Measures of the BIS/BAS Scales when Comparing the Reward Task with the Baseline and Punishment Tasks for Measures of Response Inhibition*

| Source | Measure | Task | df | *F* | *p* |
|---|---|---|---|---|---|
| Task × BAS Drive | *P* (In) | Reward vs. Baseline | 1 | 3.81 | .11 |
| | | Reward vs. Punishment | 1 | 7.68* | .04 |
| | SSRT | Reward vs. Baseline | 1 | 9.00* | .03 |
| | | Reward vs. Punishment | 1 | 20.82** | .01 |
| Error | | | 5 | | |
| Task × BAS Fun Seeking | *P* (In) | Reward vs. Baseline | 1 | 1.06 | .35 |
| | | Reward vs. Punishment | 1 | 4.24 | .10 |
| | SSRT | Reward vs. Baseline | 1 | 0.07 | .80 |
| | | Reward vs. Punishment | 1 | 2.47 | .18 |
| Error | | | 5 | | |
| Task × BAS Reward Responsiveness | *P* (In) | Reward vs. Baseline | 1 | 1.51 | .27 |
| | | Reward vs. Punishment | 1 | 3.01 | .14 |
| | SSRT | Reward vs. Baseline | 1 | 0.19 | .68 |
| | | Reward vs. Punishment | 1 | 2.58 | .17 |
| Error | | | 5 | | |

*Note.* n = 10; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time.

*$p < .05$. **$p < .01$.

There was also a near significant interaction between Task and BAS Fun Seeking when comparing the Reward task with the Punishment task, $F(1, 5) = 4.24, p < .10$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 7.5 displays the correlation between probability of inhibition on stop-trials and BAS Fun Seeking on the Baseline, Punishment, and

Reward tasks. The regression lines in panels R and P of Figure 7.5 indicate that, in general, whereas there was no apparent trend toward an association between BAS Fun Seeking score and probability of inhibition on stop-trials on the Punishment task, there was a moderate trend toward a higher BAS Fun Seeking scale score being associated with a higher probability of inhibition (i.e., stronger inhibitory control) on the Reward task, consistent with prediction. Contrary to prediction, no Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction was significant when comparing the Reward task with the Baseline task for probability of inhibition on stop-trials, $p > .05$.

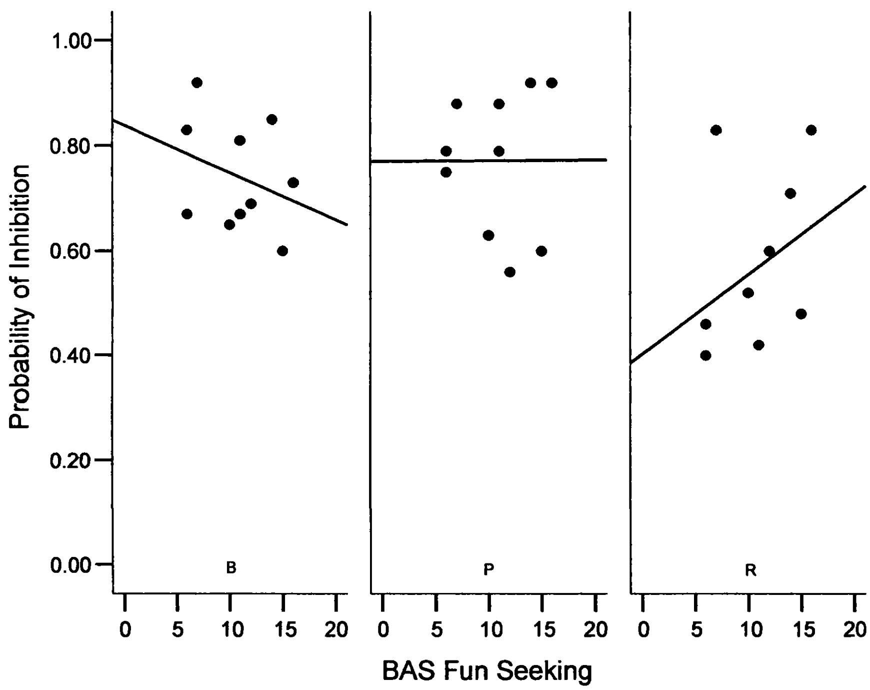


*Figure 7.5.* BAS Fun Seeking scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be less rewarding than initially expected (n = 10).

For the other measure of response inhibition, SSRT, there was a significant interaction between Task and BAS Drive when comparing the Reward task with the Baseline task, $F(1, 5) = 9.00, p < .05$, and when comparing the Reward task with the Punishment task, $F(1, 5) = 20.82, p < .01$. Figure 7.6 displays the correlation between SSRT and BAS Drive on the Baseline, Punishment, and Reward tasks. The regression lines in panels B, P and R of Figure 7.6 indicate that while, in general, there was a slight trend toward a higher BAS Drive scale score being associated with a slower SSRT on the Baseline task and a moderate trend toward this same association on the Punishment task, a higher BAS Drive scale score was related to a faster SSRT (i.e., stronger inhibitory control) on the Reward task, $p < .01$, consistent with prediction.

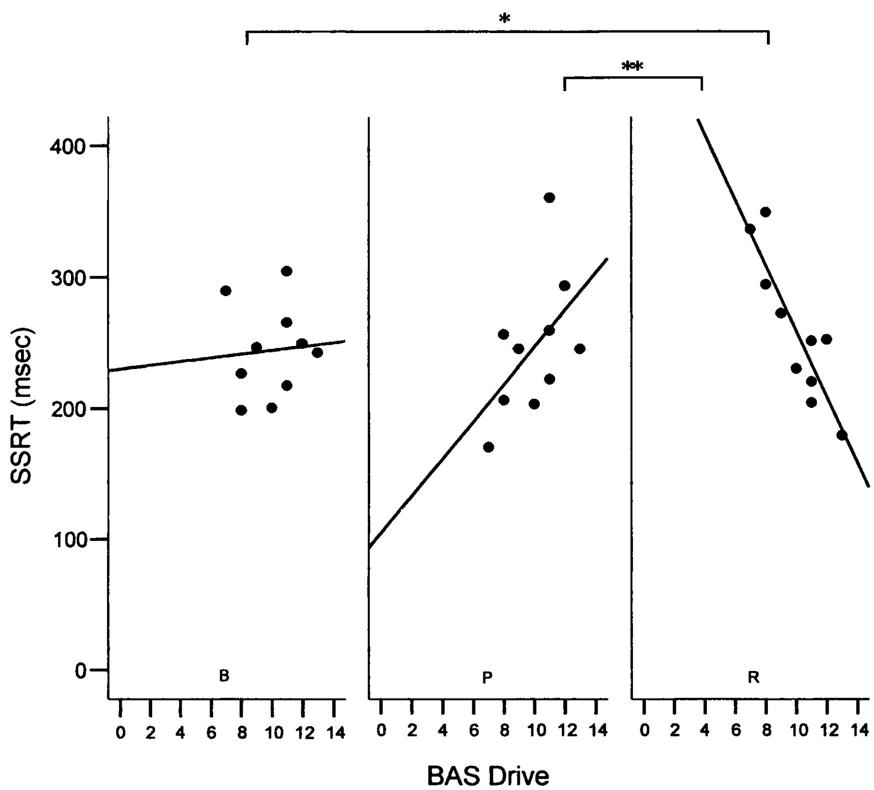


*Figure 7.6.* BAS Drive scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be less rewarding than initially expected (n = 10).

*$p < .05$. **$p < .01$.

*7.3.2.1.3 Group that perceived the Conflict task to be as or more rewarding than initially expected*

The results of the simple within-subjects contrasts are summarised in Table 7.5. Examination of Table 7.5 shows that, for SSRT, there was a significant interaction between Task and BAS Drive when comparing the Conflict task with the Baseline task, $F(1, 8) = 6.35, p < .05$. This suggests that, as expected, the response of SSRT to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 7.7 displays the correlation between SSRT and BAS Drive on the Baseline, Punishment, and Conflict tasks. The regression lines in panels C and B of Figure 7.7 indicate that, in general, whereas there was a slight trend toward a higher BAS Drive scale score being associated with a slower SSRT (i.e., weaker inhibitory control) on the Baseline task, there was a moderate trend toward the opposite association on the Conflict task, contrary to prediction. Also contrary to prediction, no Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction was significant when comparing the Conflict task with the Punishment task for SSRT, $p > .05$, or when comparing the Conflict task with the Baseline or Punishment task for the other measure of response inhibition, probability of inhibition on stop-trials, $p > .05$.

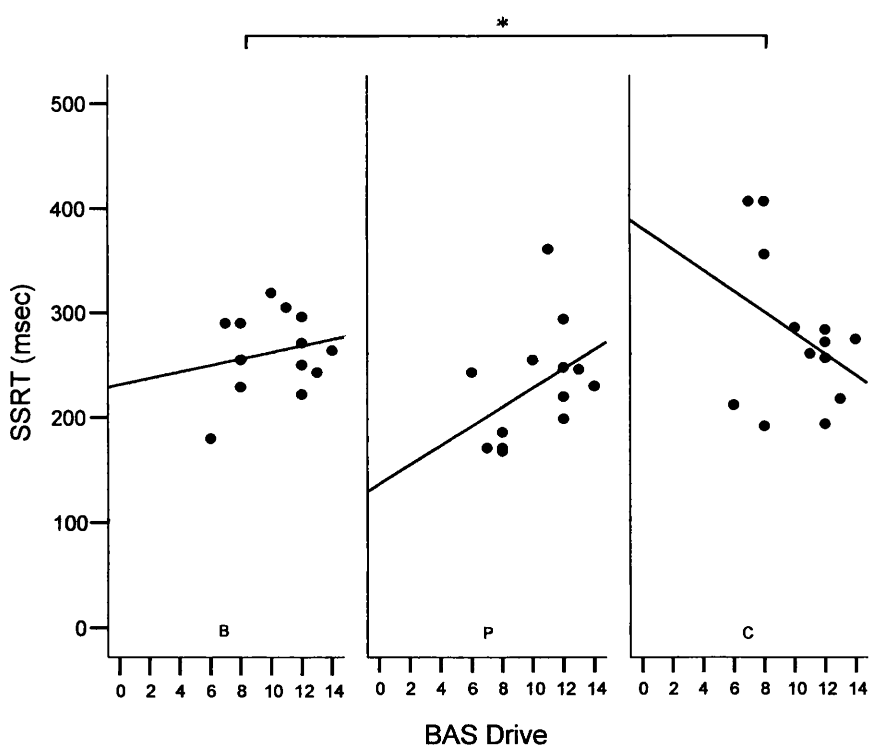


*Figure 7.7.* BAS Drive scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), and Conflict (panel C), stop-signal tasks for the group that perceived the Conflict task to be as or more rewarding than initially expected (n = 13).

*$p < .05$.

Table 7.5

*Summary of Simple Within-subjects Contrasts, for the Group that Perceived the Conflict Task to be as or More Rewarding than Initially Expected, Showing Interaction Effects between Task and BAS Measures of the BIS/BAS Scales when Comparing the Conflict Task with the Baseline and Punishment Tasks for Measures of Response Inhibition*

| Source | Measure | Task | df | *F* | *p* |
|---|---|---|---|---|---|
| Task × BAS Drive | *P* (In) | Conflict vs. Baseline | 1 | 0.28 | .61 |
| | | Conflict vs. Punishment | 1 | 0.20 | .67 |
| | SSRT | Conflict vs. Baseline | 1 | 6.35* | .04 |
| | | Conflict vs. Punishment | 1 | 1.44 | .26 |
| Error | | | 8 | | |
| Task × BAS Fun Seeking | *P* (In) | Conflict vs. Baseline | 1 | 0.03 | .87 |
| | | Conflict vs. Punishment | 1 | 0.83 | .39 |
| | SSRT | Conflict vs. Baseline | 1 | 2.22 | .17 |
| | | Conflict vs. Punishment | 1 | 2.09 | .19 |
| Error | | | 8 | | |
| Task × BAS Reward Responsiveness | *P* (In) | Conflict vs. Baseline | 1 | 0.00 | .95 |
| | | Conflict vs. Punishment | 1 | 0.59 | .47 |
| | SSRT | Conflict vs. Baseline | 1 | 1.70 | .23 |
| | | Conflict vs. Punishment | 1 | 3.47 | .10 |
| Error | | | 8 | | |

*Note.* n = 13; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time.

*$p < .05$.

*7.3.2.1.4 Group that perceived the Conflict task to be less rewarding than initially expected*

The results of the simple within-subjects contrasts are summarised in Table 7.6. Examination of Table 7.6 shows that, contrary to prediction, no Task × BAS (Drive, Fun Seeking, or Reward Responsiveness) interaction was significant, $p > .05$.

Table 7.6

*Summary of Simple Within-subjects Contrasts, for the Group that Perceived the Conflict Task to be Less Rewarding than Initially Expected, Showing Interaction Effects between Task and BAS Measures of the BIS/BAS Scales when Comparing the Conflict Task with the Baseline and Punishment Tasks for Measures of Response Inhibition*

| Source | Measure | Task | df | *F* | *p* |
|---|---|---|---|---|---|
| Task × BAS Drive | *P* (In) | Conflict vs. Baseline | 1 | 1.34 | .29 |
| | | Conflict vs. Punishment | 1 | 0.78 | .41 |
| | SSRT | Conflict vs. Baseline | 1 | 2.56 | .16 |
| | | Conflict vs. Punishment | 1 | 0.00 | .97 |
| Error | | | 6 | | |
| Task × BAS Fun Seeking | *P* (In) | Conflict vs. Baseline | 1 | 0.98 | .36 |
| | | Conflict vs. Punishment | 1 | 0.00 | .98 |
| | SSRT | Conflict vs. Baseline | 1 | 0.46 | .52 |
| | | Conflict vs. Punishment | 1 | 0.41 | .55 |
| Error | | | 6 | | |
| Task × BAS Reward Responsiveness | *P* (In) | Conflict vs. Baseline | 1 | 1.09 | .34 |
| | | Conflict vs. Punishment | 1 | 0.14 | .72 |
| | SSRT | Conflict vs. Baseline | 1 | 0.49 | .51 |
| | | Conflict vs. Punishment | 1 | 0.58 | .47 |
| Error | | | 6 | | |

*Note.* n = 11; *P* (In) = probability of inhibition on stop-trials; SSRT = stop-signal reaction time.

*7.3.2.2 Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ)*

*7.3.2.2.1 Group that perceived the Reward task to be as or more rewarding than initially expected*

Contrary to prediction, the simple within-subjects contrasts revealed no significant interaction between Task and Sensitivity to Reward (i.e., BAS) when comparing the Reward task with the

Baseline task, $F(1, 11) = 0.34$, $p > .05$, or the Punishment task, $F(1, 11) = 0.60$, $p > .05$, for probability of inhibition on stop-trials or when comparing the Reward task with the Baseline task, $F(1, 11) = 1.13$, $p > .05$, or the Punishment task, $F(1, 11) = 0.46$, $p > .05$, for SSRT.

*7.3.2.2.2 Group that perceived the Reward task to be less rewarding than initially expected*

Contrary to prediction, the simple within-subjects contrasts revealed no significant interaction between Task and Sensitivity to Reward (i.e., BAS) when comparing the Reward task with the Baseline task, $F(1, 7) = 0.42$, $p > .05$, or the Punishment task, $F(1, 7) = 0.20$, $p > .05$, for probability of inhibition on stop-trials or when comparing the Reward task with the Baseline task, $F(1, 7) = 0.17$, $p > .05$, or the Punishment task, $F(1, 7) = 4.18$, $p > .05$, for SSRT.

*7.3.2.2.3 Group that perceived the Conflict task to be as or more rewarding than initially expected*

Contrary to prediction, the simple within-subjects contrasts revealed no significant interaction between Task and Sensitivity to Reward (i.e., BAS) when comparing the Conflict task with the Baseline task, $F(1, 10) = 1.22$, $p > .05$, or the Punishment task, $F(1, 10) = 0.00$, $p > .05$, for probability of inhibition on stop-trials or when comparing the Conflict task with the Baseline task, $F(1, 10) = 0.92$, $p > .05$, or the Punishment task, $F(1, 10) = 0.67$, $p > .05$, for SSRT.

*7.3.2.2.4 Group that perceived the Conflict task to be less rewarding than initially expected*

The simple within-subjects contrasts revealed a significant interaction between Task and Sensitivity to Reward when comparing the Conflict task with the Baseline task for probability of inhibition on stop-trials, $F(1, 8) = 5.30$, $p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to BAS (as measured by this scale) differed according to Task when comparing these two tasks. Figure 7.8 displays the correlation between probability of inhibition on stop-trials and Sensitivity to Reward on the Baseline, Punishment, and Conflict tasks. The regression lines in panels B and C of Figure 7.8 indicate that, in general, consistent with prediction, whereas there was a slight trend toward a higher Sensitivity to Reward scale score being associated with a lower probability of inhibition on stop-trials (i.e., weaker inhibitory control) on the Baseline task, there was a moderate trend toward the opposite association on the Conflict task.

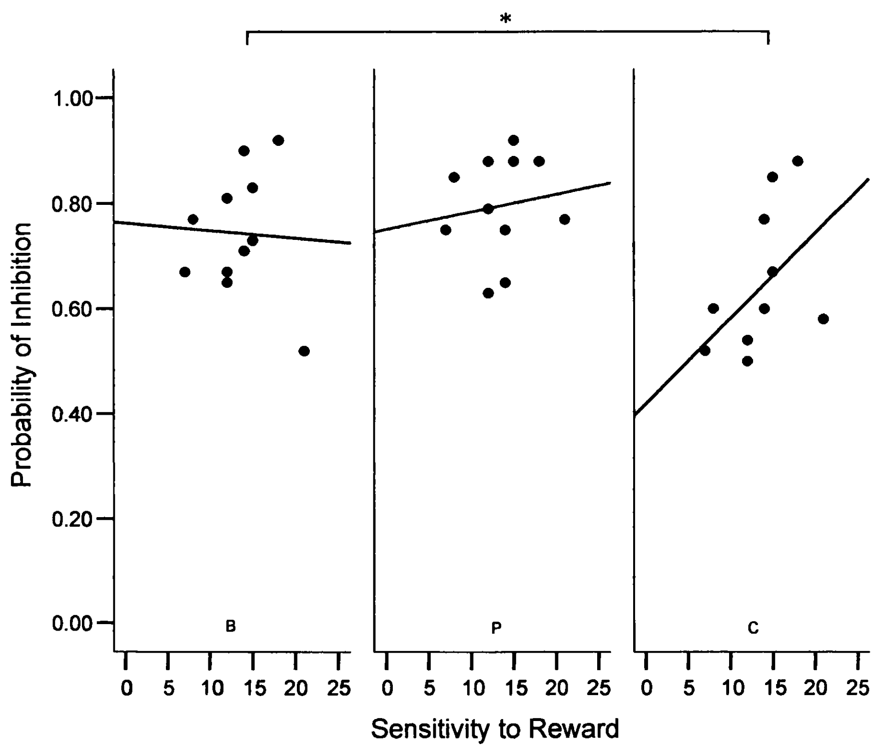


*Figure 7.8.* Sensitivity to Reward scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), and Conflict (panel C), stop-signal tasks for the group that perceived the Conflict task to be less rewarding than initially expected (n = 11).

*$p < .05$.

Contrary to prediction, there was no significant interaction between Task and Sensitivity to Reward when comparing the Conflict task with the Punishment task for probability of inhibition on stop-trials, $F(1, 8) = 1.58$, $p > .05$, or when comparing the Conflict task with the Baseline task, $F(1, 8) = 2.82$, $p > .05$, or the Punishment task, $F(1, 8) = 0.28$, $p > .05$, for the other measure of response inhibition, SSRT.

*7.3.2.3 Revised Eysenck Personality Questionnaire short scale (EPQ-RS)*

*7.3.2.3.1 Group that perceived the Reward task to be as or more rewarding than initially expected*

Contrary to prediction, the simple within-subjects contrasts revealed no significant interaction between Task and Extraversion when comparing the Reward task with the Baseline task, $F(1, 9) = 0.04$, $p > .05$, or the Punishment task, $F(1, 9) = 0.14$, $p > .05$, for probability of inhibition on stop-trials or when comparing the Reward task with the Baseline task, $F(1, 9) = 0.08$, $p > .05$, or the Punishment task, $F(1, 9) = 1.14$, $p > .05$, for SSRT.

*7.3.2.3.2 Group that perceived the Reward task to be less rewarding than initially expected*

The simple within-subjects contrasts revealed, for SSRT, a significant interaction between Task and Extraversion when comparing the Reward task with the Baseline task, $F(1, 5) = 15.39$, $p < .05$, and a near significant interaction between Task and Extraversion when comparing the Reward task with the Punishment task, $F(1, 5) = 5.96$, $p = .06$. This suggests that, as expected, the response of SSRT to Extraversion differed according to Task when comparing the Reward task with the Baseline task and when comparing the Reward task with the Punishment task. Figure 7.9 displays the correlation between SSRT and Extraversion on the Baseline, Punishment, and Reward tasks. The regression lines in panels R, B and P of Figure 7.9 indicate that, consistent with prediction, while a higher score on the Extraversion scale was related to a faster SSRT (i.e., stronger inhibitory control) on the Reward task, $p = .07$, there was a slight trend toward the opposite association on the Baseline task and no apparent trend toward an association between Extraversion score and SSRT on the Punishment task.

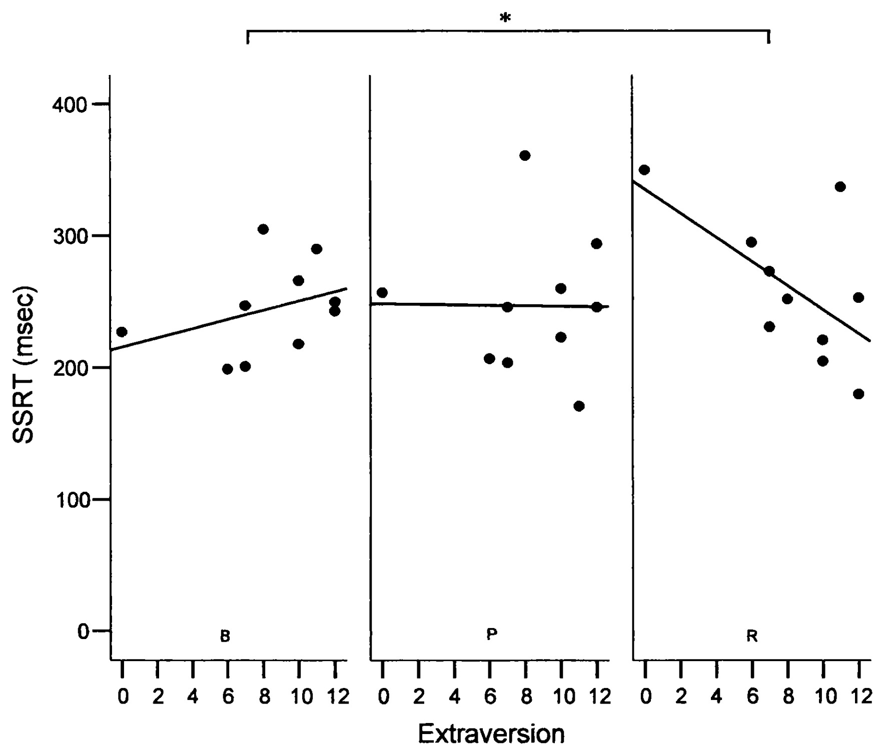


*Figure 7.9.* Extraversion scores and stop-signal reaction time (SSRT) (with regression line) for Baseline (panel B), Punishment (panel P), and Reward (panel R), stop-signal tasks for the group that perceived the Reward task to be less rewarding than initially expected (n = 10).

$^*p < .05$.

For the other measure of response inhibition, probability of inhibition on stop-trials, there was no significant interaction between Task and Extraversion when comparing the Reward task with the Baseline task, $F(1, 5) = 0.25, p > .05$, or the Punishment task, $F(1, 5) = 1.09, p > .05$, contrary to prediction.

*7.3.2.3.3 Group that perceived the Conflict task to be as or more rewarding than initially expected*

Contrary to prediction, the simple within-subjects contrasts revealed no significant interaction between Task and Extraversion when comparing the Conflict task with the Baseline task,

$F(1, 8) = 0.01, p > .05$, or the Punishment task, $F(1, 8) = 0.22, p > .05$, for probability of inhibition on stop-trials or when comparing the Conflict task with the Baseline task, $F(1, 8) = 1.02, p > .05$, or the Punishment task, $F(1, 8) = 1.17, p > .05$, for SSRT.

*7.3.2.3.4 Group that perceived the Conflict task to be less rewarding than initially expected*

The simple within-subjects contrasts revealed a significant interaction between Task and Extraversion when comparing the Conflict task with the Baseline task for probability of inhibition on stop-trials, $F(1, 6) = 10.19, p < .05$. This suggests that, as expected, the response of probability of inhibition on stop-trials to Extraversion differed according to Task when comparing these two tasks. Figure 7.10 displays the correlation between probability of inhibition on stop-trials and Extraversion on the Baseline, Punishment, and Conflict tasks.

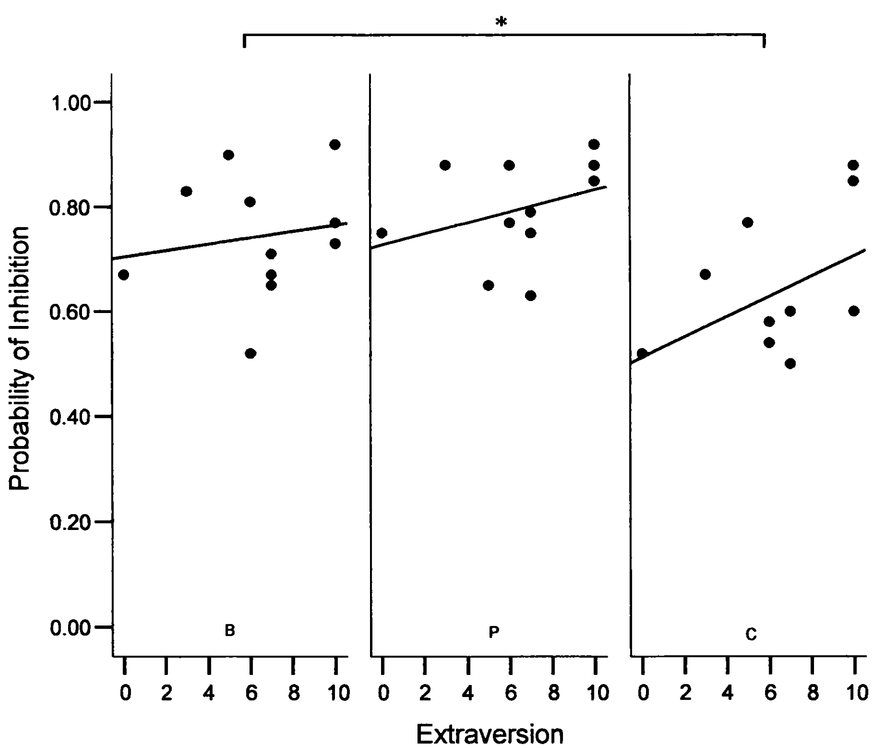


*Figure 7.10.* Extraversion scores and probability of inhibition on stop-trials (with regression line) for Baseline (panel B), Punishment (panel P), and Conflict (panel C), stop-signal tasks for the group that perceived the Conflict task to be less rewarding than initially expected (n = 11).

*$p < .05$.

The regression lines in panels B and C of Figure 7.10 indicate that, in general, there was a slight trend toward a higher Extraversion score being associated with a higher probability of inhibition on stop-trials (i.e., stronger inhibitory control) on both the Baseline and Conflict tasks but that this association was strongest on the Conflict task, consistent with prediction.

Contrary to prediction, there was no significant interaction between Task and Extraversion when comparing the Conflict task with the Punishment task for probability of inhibition on stop-trials, $F(1, 5) = 0.00$, $p > .05$, or when comparing the Conflict task with the Baseline task, $F(1, 5) = 3.01$, $p > .05$, or the Punishment task, $F(1, 5) = 1.83$, $p > .05$, for the other measure of response inhibition, SSRT.

### 7.4 Discussion

This study aimed to follow-up some of the unexpected findings obtained in the study presented in chapter 4 by investigating one potential explanation for their presence: the idea that participants' reinforcement expectancies might influence associations between self-reported sensitivity to reward/punishment and actual responses to reward/punishment on the stop-signal task. Little exists in the previous literature investigating reward expectancies and actual perceived reward. It was anticipated that by employing a similar method to that used by Kambouropoulos and Staiger (2004) for assessing levels of reinforcement expectancies (see section 7.1.1 for description) in relation to the stop-signal tasks (assumed to tap into BIS/BAS functioning), the unexpected findings concerning inhibitory control, BAS activity, and Extraversion presented in chapter 4 could be further investigated and perhaps explained.

To test predictions based on the assumption that 'participant-perceived reward needs to be equal to or greater than expected levels of reward for appetitive manipulations to be considered effective and for positive relationships between BAS traits and actual reactions to reward to be observed' (Kambouropoulos & Staiger, 2004, p. 1155), participants were assigned to one of two groups for analyses focusing on Reward task performance: (1) group that perceived the Reward task to be as or more rewarding than initially expected; or (2) group that perceived the Reward task to be less rewarding than initially expected. Participants were also assigned to one of two groups for analyses focusing on Conflict task performance: (1) group that perceived the Conflict task to be as or more rewarding than initially expected; or (2) group that perceived the Conflict task to be less rewarding than initially expected. Group assignment was determined by the difference score obtained from the two scales used to assess levels of reinforcement expectancies in relation to the Reward and Conflict tasks.

*7.4.1 Personality and inhibitory control on tasks perceived to be as or more rewarding than expected*

It was predicted that higher self-reported BAS activity and Extraversion should be most strongly associated with weaker inhibitory control (compared to on the Baseline and Punishment tasks) on the Reward and Conflict tasks (consistent with predictions outlined in chapter 4, section 4.1.2) among participants that perceive these tasks to be as or more rewarding than initially expected. Evidence was produced showing that, for the group that perceived the Reward task to be as or more rewarding than initially expected, higher self-reported BAS activity (assessed by the BAS Fun Seeking scale) was associated with weaker inhibitory control (based on both measures of response inhibition) on the Reward task, and that this association was stronger on the Reward task than on the Baseline (based on probability of inhibition on stop-trials) and Punishment (based on both measures of response inhibition) tasks, consistent with prediction. Also in line with prediction, for this same group of participants, a higher score on another BAS measure (the BAS Drive scale) was near significantly related to weaker inhibitory control (based on probability of inhibition on stop-trials) on the Reward task, although this association was not found to be significantly stronger than on the Baseline or Punishment tasks.

Evidence was produced, in line with prediction, showing that, for the group that perceived the Conflict task to be as or more rewarding than initially expected, higher self-reported BAS activity (assessed by the BAS Drive scale) was associated with weaker inhibitory control (based on probability of inhibition on stop-trials) on the Conflict task, although this association was not found to be significantly stronger than on the Baseline or Punishment tasks. Also in line with prediction, for this same group of participants, a higher score on another BAS measure (the BAS Fun Seeking scale) was near significantly related to weaker inhibitory control (based on the same measure of response inhibition, probability of inhibition on stop-trials) on the Conflict task, although again this association was not found to be significantly stronger than on the Baseline or Punishment tasks. Contrary to prediction, however, for this same group of participants, a higher score on the BAS Reward Responsiveness scale was related to stronger inhibitory control (based on SSRT) on the Conflict task and evidence was produced to suggest that higher self-reported BAS activity (assessed by the BAS Drive scale) was more strongly associated with stronger inhibitory control (again based on SSRT) on the Conflict task compared to on the Baseline task.

In general, the findings discussed above indicate that positive relationships between BAS activity and actual reactions to reward were indeed observed on the stop-signal task when participant-perceived reward was equal to or greater than expected levels of reward, consistent with expectations based on Kambouropoulos and Staiger's (2004) assumptions and findings concerning other behavioural tasks. In the study presented in chapter 4, the majority of the results obtained concerning associations between self-reported BAS activity and performance on the Reward and Conflict tasks were theoretically inconsistent. The study was, however, limited by the fact that, unlike in the present study, levels of subjective reward were not directly assessed to ensure that manipulations of motivation on the Reward and Conflict tasks were effective. The results obtained in the present study, therefore, emphasise the importance of, as indicated by Corr (2001), assessing levels of subjective reward in any study employing Gray's RST to investigate reactions to rewarding and punishing situations to ensure that manipulations of motivation (in particular appetitive; see Corr 2002a) are effective.

No significant evidence was produced to support the prediction that higher self-reported Extraversion should be most strongly associated with weaker inhibitory control (compared to on the Baseline and Punishment tasks) on the Reward and Conflict tasks among participants that perceive these tasks to be as or more rewarding than initially expected. However, although not significant, correlations between Extraversion and response inhibition measures on the Reward and Conflict tasks were in the predicted direction (unlike in the study presented in chapter 4, in which levels of subjective reward were not directly assessed). It is possible that had larger sample sizes been used, these correlations might have been found to reach significance.

### *7.4.2 Personality and inhibitory control on tasks perceived to be less rewarding than expected*

It was predicted that higher self-reported BAS activity and Extraversion should be most strongly associated with stronger inhibitory control (compared to on the Baseline and Punishment tasks) on the Reward and Conflict tasks (i.e., theoretically inconsistent associations between self-report measures of BAS/Extraversion and actual responses to rewarding stimuli present on these tasks should be observed; consistent with some of the unexpected findings presented in chapter 4) among participants that perceive these tasks to be less rewarding than initially expected. Evidence was produced showing that, for the group that perceived the Reward task to be less rewarding than initially expected, higher self-reported BAS activity (assessed by the BAS Drive and BAS Fun Seeking scales) was associated with stronger inhibitory control (based on SSRT) on the Reward task, in line with prediction. For this same group, the response of inhibitory control (as measured by SSRT) to BAS (as measured by the BAS Drive scale) was shown to be different on the Reward task compared to on the Baseline and Punishment tasks. The difference was that while there was a trend toward higher self-reported BAS activity being associated with weaker inhibitory control (i.e., a trend toward theoretically consistent associations) on the Baseline and Punishment tasks, there was a strong association in the opposite direction on the Reward task for the group that perceived this task to be less rewarding than initially expected, consistent with prediction.

Also, for this same group of participants, a higher score on the BAS Drive scale was near significantly related to stronger inhibitory control based on the other measure of response inhibition, probability of inhibition on stop-trials, on the Reward task and evidence was produced showing that this association was stronger than on the Punishment task, consistent with prediction. Near significant evidence was produced showing a similar pattern of results with the BAS Fun Seeking scale. For this same group, the response of inhibitory control (as measured by SSRT) to Extraversion was shown to be different on the Reward task compared to on the Baseline and Punishment tasks. The difference was that while there was a slight trend toward higher self-reported Extraversion being associated with weaker inhibitory control (i.e., a slight trend toward a theoretically consistent association) on the Baseline task and no apparent trend toward an association on the Punishment task, higher self-reported Extraversion was near significantly related to stronger inhibitory control on the Reward task for the group that perceived this task to be less rewarding than initially expected, consistent with prediction.

Evidence was produced showing that, for the group that perceived the Conflict task to be less rewarding than initially expected, the response of inhibitory control (as measured by probability of inhibition on stop-trials) to BAS (as measured by the Sensitivity to Reward scale) was shown to be different on the Reward task compared to on the Baseline task. The difference was that while there was a slight trend toward higher self-reported BAS activity being associated with weaker inhibitory control (i.e., a slight trend toward a theoretically consistent association) on the Baseline task, there was a moderate trend toward the opposite association on the Conflict task for the group that perceived this task to be less rewarding than initially expected, consistent with prediction. Evidence was produced showing a similar pattern of results with self-reported Extraversion for this same group.

In general, the pattern of findings discussed above were consistent with the unexpected findings obtained concerning associations between self-reported BAS/Extraversion and inhibitory control on the Reward and Conflict tasks in the study presented in chapter 4. The results appear to confirm that, as suggested in chapter 4 (section 4.4.3), it is possible that putative appetitive tasks may elicit frustrative non-reward (aversive motivation) in certain participants who have high initial expectations of reward, leading to apparently theoretically inconsistent relationships between reactions to (assumed) rewarding situations and BAS activity (and Extraversion). Since, in the present study, approximately half of the participants perceived the Reward task to be less rewarding than expected and approximately half of the participants perceived the Conflict task to be less rewarding than expected, it is likely that a similar proportion of participants in the study presented in chapter 4 might have perceived these tasks in the same, frustrating, way. Given how different the pattern of results were revealed to be between groups that perceived tasks to be as or more rewarding than expected and groups that perceived tasks to be less rewarding than expected, the apparent lack of significant associations (or trend towards theoretically inconsistent associations) between task performance and BAS (and Extraversion) measures obtained in the study presented in chapter 4 could have been due to these different groups (unidentified at the time) cancelling out each other's effects (or one group's (i.e., the group that perceived the Reward task to be less rewarding than expected) effects slightly dominating the other group's (i.e., the group that perceived the Reward task to be as or more rewarding than expected) effects).

### *7.4.3 Implications, limitations and future directions*

To summarise, the results indicate, in accordance with Kambouropoulos and Staiger's (2004) findings (using similar methodology and different behavioural tasks), that 'participant-perceived reward needs to be equal to or greater than expected levels of reward for appetitive manipulations to be considered effective and for positive relationships between BAS traits and actual reactions to reward to be observed' (Kambouropoulos & Staiger, p. 1155). The implications of these findings for future research appear valuable: they confirm the importance (as indicated by Corr, 2001) of assessing levels of subjective reward in any study employing Gray's RST to investigate reactions to rewarding and punishing situations to ensure that manipulations of motivation (in particular appetitive; see Corr 2002a) are effective. The study presented in chapter 4 provides an excellent example of how failure to make these important assessments can result in apparently unexpected and misleading associations between BIS/BAS activity and reactions to punishing/rewarding situations. Having made these assessments and analysed the data accordingly in the present study, theoretically consistent associations were revealed between BAS activity (as well as Extraversion) and reactions to rewarding/punishing stimuli on the stop-signal tasks.

Limitations of this study include the small sample sizes. Ideally, for analyses involving correlations (as in the present study), larger groups of participants than those found in the present study should be recruited and tested to provide more reliable evidence from which to draw conclusions. However, this study was intended as a small follow-up study to chapter 4; to explore the potential of one possible explanation for some of the unexpected findings obtained. Despite the use of small sample sizes, consistent and promising results were obtained in support of this potential explanation. Future research could look at confirming the findings of this study in considerably larger samples. Something else that could be investigated in future research with larger samples would be differences in reinforcement expectancies (and associations between task performance and BIS/BAS) between the two groups that performed the stop-signal tasks in different orders (Punishment task before Reward task or Reward task before Punishment task). This issue was discussed in chapter 4, section 4.4.3, in light of exploratory analyses revealing that a higher BAS Drive score was related to a stronger inhibitory control on the Reward task (theoretically inconsistent and contrary to prediction) but only for the group that performed the Punishment task before the Reward task. Since it would have involved dividing the already small sample sizes into even smaller samples, this issue was not investigated in the present study but should certainly be examined in future research.

Another limitation, which again has potential implications for future investigation using the stop-signal tasks, was that this study focused exclusively on levels of reinforcement expectancies and associations between BAS/Extraversion and inhibitory control on the Reward and Conflict tasks. Beyond the scope of this small follow-up study, future research could investigate levels of reinforcement expectancies and associations between BIS/FFFS and inhibitory control on the stop-signal tasks. Such future investigation, outlined in greater detail in section 4.4.3 of chapter 4, could help to confirm the role of reinforcement expectancies in producing theoretically consistent associations between BIS/FFFS activity and stop-signal task performance (just as the findings of the present study confirmed the role of reinforcement expectancies in producing theoretically consistent associations between BAS activity, Extraversion, and inhibitory control on the stop-signal task). The next chapter discusses, among other issues, the present study's findings in relation to the other experimental studies within this thesis.

# Chapter 8

# Discussion

This thesis aimed to investigate inhibitory control, reinforcement and personality, as well as implications for gambling behaviour. Toward this end, a number of experimental studies were conducted, each with their own specific aims and predictions, investigating various interrelated aspects contributing to the overall aims of the thesis. This final chapter sets out the main findings of the investigation, and relates these to the previous literature. In this discussion, each hypothesis derived from the previous relevant literature is examined in light of evidence presented in this thesis for possible substantiation, contradiction, or innovation. The limitations are then presented, followed by overall implications and ideas for future research. Finally, conclusions are drawn as to the contribution made by this thesis to better understanding inhibitory control, reinforcement, personality, and gambling behaviour.

## 8.1 Inhibitory control and reinforcement

### *8.1.1 Stop-signal task performance*

Significant evidence was produced in chapters 3, 4, and 6 to support the hypothesis that inhibitory control on the stop-signal task could be modified using different response contingencies (i.e., reinforcement). The vast majority of previous studies utilising the paradigm to investigate inhibitory control have focused explicitly on 'standard' versions of the task, with no specific motivational stimuli (see chapter 1, section 1.1.1). Of the two previous attempts that have been made to design and implement tasks with specific rewarding and punishing contingencies (Oosterlaan & Sergeant, 1997; Rodriguez-Fornells et al., 2002), both were limited in certain ways as highlighted in chapter 1, section 1.1.1.1. Therefore, for the purposes of the present thesis, four unique stop-signal tasks with different response contingencies were developed (chapter 3), each of which is described in detail in section 2.1.1 of chapter 2 (except for the original Punishment, Reward, and Conflict tasks used in Experiment 1 of chapter 3; descriptions of these tasks can be found in chapter 3, section 3.1.2.2.1). These tasks were shown to be valid and reliable measures of the inhibition process based on evidence collected within this thesis (chapters 3, 4, and 6).

Negative slope functions were generated relating probability of inhibition to stop-signal delay on each of the four tasks within chapters 3, 4, and 6. Amongst other things, the presence of these slopes provides validation of successful employment of appropriate delays (see chapter 1, section 1.1). According to the race model, and as demonstrated in previous research, stopping becomes increasingly more difficult the later the stop-signal is presented in relation to the go-signal (e.g., Lappin & Eriksen, 1966; Logan, 1994; Logan & Cowan, 1984). In accordance with this race model assumption and consistent with previous research using the same stop-signal delays (Fillmore and Rush, 2002; Fillmore et al., 2001, 2002), probability of inhibition was found to decrease in an orderly, linear fashion as the stop-signal delays increased from 50 to 350-ms on all four tasks, in each of the experiments presented in chapters 3, 4, and 6. The experiments presented in these chapters also produced consistent replication of results concerning task differences in response inhibition (and response execution) on the four stop-signal tasks, demonstrating their strong reliability.

A number of specific hypotheses concerning inhibitory control on the stop-signal task in the presence of different response contingencies (i.e., reinforcement) were generated based on Avila and Parcet's (2001) argument that, although the standard task based on Logan's original has no specific motivational stimuli, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (p. 983). The first of these was that the introduction of specific punishing stimuli associated with response errors (including not stopping for stop-signals) should result in an increased care in task performance and, consequently, stronger inhibitory control on the task. The second was that the introduction of specific rewarding stimuli associated with speeded responses to the go-signal should result in an increased motivation in approaching this go-signal and, consequently, weaker inhibitory control on the task. The third, and final, of these hypotheses was that the introduction of the combination of both specific punishing and rewarding stimuli (thus creating an approach-avoidance conflict situation) should result in similar inhibitory control on the task (compared to on the standard task). Evidence was produced in chapters 3 (Experiments 2 and 3) and 4 to support these hypotheses; compared to on the Baseline (i.e., standard) task, participants were shown to have a stronger inhibitory control on the Punishment task, a weaker inhibitory control on the Reward task, and a similar inhibitory control on the Conflict task. Other task differences in response inhibition (as well as in response execution) were also revealed and discussed in these chapters (see chapters 3 and 4 for specific details).

No previous research has investigated the influence of these four stop-signal task contingencies on inhibitory control and task performance within-subjects. Oosterlaan and Sergeant (1997) used a stop-signal task with reward contingencies and a stop-signal task with response cost contingencies to examine whether AD/HD children's impaired response inhibition on the stop-signal paradigm reflects a motivation deficit. Unlike in the present thesis, children earned credits for successful response inhibition (i.e., successfully stopping for stop-signals) in Oosterlaan and Sergeant's reward condition and the study did not allow the authors to determine the effects of rewarding and punishing response contingencies on the stop-signal task as such, since they did not include a condition in which there was no specific motivational stimuli. In the present thesis, the specific rewarding stimuli was associated with successful response execution (i.e., responding fast with the correct key) rather than with successful response inhibition as a means of enhancing the appetitive properties of the go-task stimuli (i.e., the letters without a stop-signal) increasing participants' interest and motivation in approaching (with a computer key press response) this stimuli on both the Reward and Conflict tasks. By not including a condition in which there was no specific motivational stimuli, Oosterlaan and Sergeant left open the possibility that response contingencies effect inhibitory control relative to no specific motivational stimuli. The results obtained in this thesis (chapters 3, 4, and 6) show that different response contingencies did effect inhibitory control on the stop-signal task relative to no specific motivational stimuli.

The finding that inhibitory control was similar on the Conflict task compared to on the Baseline task (chapter 3, Experiments 2 and 3; chapter 4), consistent with hypothesis, runs contrary to the findings of Rodriguez-Fornells et al.'s (2002) study in which the proportion of successfully inhibited responses on stop-trials was found to increase and SSRT to decrease during performance of their stop-signal task with specific rewarding/punishing stimuli (i.e., their version of the Conflict task creating an approach-avoidance conflict situation) compared to during performance of the standard task. Rodriguez-Fornells et al.'s findings indicated an increased inhibitory control on the stop-signal task in the presence of specific rewarding and punishing stimuli. However, because Rodriguez-Fornells et al. reversed the assignment of responses to the two subsets of stimulus letters in their conflict condition (which was always the second condition) compared to their standard condition (the first condition) in an attempt to avoid practise effects, participants first had to inhibit the learned response from the first (standard) condition and then respond in the new way whilst performing the second (conflict) condition, resulting in an unreliable comparison between the two tasks. In the present thesis, the assignment of responses to the two subsets of stimulus letters were kept the same for all four conditions (tasks) to allow for a more reliable comparison between the four tasks. The order of task administration was counterbalanced across participants in an attempt to control for any possible confounding extraneous variables (e.g., practise effects) and then any order effects were investigated. No task order effects (concerning the stop-signal tasks) were revealed in any of the experimental studies within this thesis.

### *8.1.2 Card perseveration (CP) task performance*

It was hypothesised that, on the CP task, imposing a forced 5-s waiting period alone (following immediate response feedback) should be sufficient in resulting in greater attention being paid to response feedback on each trial and thus an earlier awareness of the changing task contingencies and, consequently, lesser response perseveration (i.e., stronger inhibitory control) compared to on the standard task (no forced pause, immediate feedback only). Evidence was produced in support of this hypothesis in chapters 5 and 6. This hypothesis was generated based on the findings of Newman et al.'s (1987) study, in which it was demonstrated that control participants (as well as psychopathic participants) played fewer cards and won more money (i.e., perseverated less) on the task with a cumulative feedback display accompanied by a 5-s waiting period (during which they were prevented from making another response) than on the task with immediate feedback only (i.e., the standard task). Since Newman et al. did not include a condition with immediate feedback only accompanied by a 5-s waiting period during which no responses could be made, it was unclear as to whether or not the 5-s waiting period would have had the same effects without the presence of a cumulative feedback display. The authors 'reasoned that forcing subjects to pause after response feedback would improve their use of information about the changing probability of punishment and would reduce perseveration' (Newman et al., p. 146). The results obtained in chapters 5 and 6 demonstrated that participants' perseveration was reduced through forcing them to pause after response feedback even without the presence of a cumulative display of information about the changing probability of punishment (the potential implications of which are discussed below, in section 8.6).

### *8.1.3 Slot machine simulation performance*

It was hypothesised that computerised slot machine simulation performance (i.e., gambling behaviour) should be expected to vary as a function of percentage payback (i.e., overall rate of reinforcement). Evidence was produced in support of this hypothesis in chapters 5 and 6. The results run contrary to those of Weatherly and Brandt's (2004) study, in which the authors argued that both their experiments produced results demonstrating that participants' 'gambling behavior [on computerised slot machine simulations] did not vary as a function of payback percentage' (p. 33). However, whereas Weatherly and Brandt employed three (relatively high) percentage payback values (75%, 83% and 95%) on the slot machine simulations in their study, only two different values were employed in the present thesis: (1) a high percentage payback rate of 70%; and (2) a low percentage payback rate of 30%. As expected, participants bet a lower total number of credits on the slot machine simulation with low percentage payback rate than on the simulation with high percentage payback rate (chapters 5 and 6). These findings indicate that the high rate of punishment on the simulation with low percentage payback rate resulted in more cautious gambling behaviour, in an attempt to minimise overall loss. Thus the results obtained in chapters 5 and 6 suggest that, as expected, gambling behaviour on computerised slot machine simulations can vary as a function of percentage payback rate, so long as sufficiently varied rates are employed, and that perhaps the three different rates used in Weatherly and Brandt's study were simply not varied enough to produce significantly different gambling behaviour.

## 8.2 Personality in relation to inhibitory control, reinforcement, and behavioural inhibition

### *8.2.1 Stop-signal task performance*

Since it could be argued that, in the stop-signal paradigm, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983) it was hypothesised that: higher self-reported BAS activity and Extraversion should be associated with weaker inhibitory control on the stop-signal task, and that these associations should be strongest on tasks with specific rewarding stimuli associated with speeded responses to the go-signal; and higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with stronger inhibitory control on the stop-signal task, and that these associations should be strongest on tasks with specific punishing stimuli associated with response errors (including not stopping for stop-signals).

Evidence was produced in chapters 4 and 7 showing that self-reported personality was associated with inhibitory control on each of the four stop-signal tasks. However, failure to assess reinforcement expectancies in relation to the tasks and to analyse data in light of them in chapter 4 appeared to lead to a number of these associations being theoretically inconsistent and contrary to hypotheses. For example, evidence was produced relating higher BAS activity and higher Extraversion to stronger inhibitory control on the Reward task (a task with putative specific rewarding stimuli associated with speeded responses to the go-signal). Such apparently unexpected findings were then followed-up in the study presented in chapter 7 (in which reinforcement expectancies were assessed in relation to the two tasks with putative specific rewarding stimuli present (i.e., the Reward and Conflict tasks) and associations between self-reported BAS activity and Extraversion and inhibitory control were analysed in light of them) and as a result data with greater validity was produced to test hypotheses concerning these particular personality measures.

Evidence was produced in chapter 7, in accordance with Avila and Parcet's (2001) findings and consistent with hypothesis, showing that higher self-reported BAS activity was associated with weaker inhibitory control on the Baseline (standard) task. However, this significant evidence was limited to analyses involving certain reinforcement expectancy groups (see Table 7.2, chapter 7), perhaps explaining the lack of a significant association between BAS activity and inhibitory control on this task revealed in chapter 4. Nevertheless, these results provide theoretically consistent findings with the assumptions of RST based on Avila and Parcet's argument that, although the standard task based on Logan's original lacks any specific motivational stimuli, the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response' (p. 983). Unlike any previous study in the literature, chapter 7 produced evidence indicating that higher self-reported BAS activity was more strongly associated with weaker inhibitory control on the stop-signal task with specific rewarding contingencies (associated with speeded responses on go-trials) (the Reward task) than on tasks lacking specific rewarding contingencies (Baseline and Punishment tasks), consistent with hypothesis based on the assumptions of RST. This evidence was limited to analyses involving the group that perceived the Reward task to be as or more rewarding than expected (thereby representing an adequate input to the BAS).

For the other stop-signal task with specific rewarding contingencies, the Conflict task, mixed results were produced in chapter 7 concerning the association of self-reported BAS activity with measures of response inhibition in the group that perceived it to be as or more rewarding than expected (thereby representing an adequate input to the BAS), some in support of and some in contradiction to hypotheses (see section 7.4.1). This particular task, unlike the Reward task, had not only specific rewarding stimuli associated with speeded responses to the go-signal but also specific punishing stimuli associated with response errors (including not stopping for stop-signals), thus creating an approach-avoidance conflict situation (rather than an almost purely approach situation as on the Reward task). The results obtained suggest that higher self-reported BAS activity was associated with weaker inhibitory control on the stop-signal task, and that this association was strongest on the task in the presence of specific rewarding contingencies only. The mixture of findings concerning the association of BAS activity with inhibitory control on the Conflict task could be explained in terms of the BIS interacting with the BAS in some way (due to the presence of both specific punishing and rewarding stimuli creating a conflict situation on this task) rather than these systems being independently associated with the punishing/rewarding contingencies present on this task (see section 8.5 below for elaboration on this idea based on the 'joint subsystems hypothesis' (Corr, 2001)).

No significant evidence was produced showing that higher self-reported Extraversion was associated with weaker inhibitory control on the Baseline task, contrary to hypothesis based on arousal theory. Avila and Parcet (2001) also found no relation between this dimension and inhibitory control on their stop-signal task (which was similar to the Baseline task), indicating that this measure may not be sensitive to inhibitory control measured by the standard task (no specific motivational stimuli). Avila and Parcet conceived, post-hoc, one possible explanation for this unexpected result in their study:

> That the mechanisms leading to a poorer inhibitory control from an overactive BAS and an underactive BIS would be independent, and could not be acting simultaneously . . . Since the extraversion dimension is reflecting the balance of BIS/BAS activation, this dimension would not be specifically related to the disinhibition mechanisms derived from an underactive BIS and an overactive BAS. (p. 983-984)

However, the Extraversion measure was shown to be positively related to weaker inhibitory control on the Conflict task, consistent with hypothesis, for participants that perceived this task to be as or more rewarding than expected (chapter 7), and this measure was also found to be negatively related to weaker inhibitory control on the Reward task among participants that perceived this task to be less rewarding than expected (eliciting frustrative non-reward) (chapter 7) and among participants in chapter 4 (in which reinforcement expectancies in relation to the tasks were not assessed). Thus, it appears that this measure was sensitive to inhibitory control measured by stop-signal tasks with specific motivational stimuli present, suggesting that on the standard task, although it could be argued that the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), with no specific motivational stimuli present to reinforce the presumed rewarding and punishing cues, the reinforcement cues may simply not be sufficiently potent to significantly tap into the Extraversion dimension.

The Baseline (standard) task was similar to that used by Avila and Parcet (2001). Avila and Parcet demonstrated that low BIS was associated with impaired inhibitory control on the stop-signal task in a sample of female undergraduates. In accordance with these findings, evidence was produced in chapter 4 indicating that higher self-reported BIS activity was related to stronger inhibitory control on the Baseline task, consistent with hypothesis, but only in exploratory analyses within the female group of participants. Numerous other gender (as well as task order) differences in associations between self-reported measures of BIS activity (as well as FFFS activity and Neuroticism) and response inhibition on the various stop-signal tasks were revealed and discussed in detail in chapter 4, section 4.1.1. Altogether, gender and task order differences aside, results obtained concerning self-reported BIS activity, FFFS activity, Neuroticism, and the associations of these personality measures with inhibitory control on and across the four stop-signal tasks employed (chapter 4) were intriguing. These findings were discussed in detail in relation to hypotheses in section 4.2.2 of chapter 4 and so a general summary only is presented for discussion here. Overall, the results obtained indicate that while higher reactivity in these personality dimensions was more strongly related, as hypothesised, to stronger inhibitory control on the stop-signal task in the presence of specific punishing stimuli only (Punishment task) than in the presence of no specific motivational stimuli (Baseline task) and than in the presence of specific rewarding stimuli only (Reward task), higher reactivity in these personality dimensions was related to weaker inhibitory control on the stop-signal task in the presence of specific rewarding stimuli, contrary to expectations. It was suggested that these particular unexpected findings might be explained in terms of the confounding influence of reinforcement expectancies, in relation to the tasks, having not been assessed and controlled for.

Just as it is theoretically possible (and was demonstrated on the Reward and Conflict tasks in chapter 7) for the omission of expected reward to elicit frustrative non-reward (aversive motivation), it is also possible, in a symmetrical manner, for the omission of expected punishment to elicit relief of non-punishment (appetitive motivation). For some participants (i.e., high BIS/FFFS activity and high Neuroticism), the Reward task (and the Conflict task) might not have been as punishing as they expected it to be, resulting in relief of non-punishment leading to approach behaviour on go-trials (i.e., the specific rewarding stimuli) and, thus, weaker inhibitory control on this task. Unfortunately, due to certain limitations, this particular idea was not followed-up with empirical investigation in the present thesis (although evidence was produced indicating the influence of reinforcement expectancies in relation to the Reward and Conflict tasks on associations between BAS activity/Extraversion and response inhibition in chapter 7, thus providing support for the potential validity of such an explanation). It could be beneficial for future research to pursue this idea, using the stop-signal tasks and perhaps employing a similar method for assessing levels of reinforcement expectancies as used in chapter 7, in order to clarify its validity.

### *8.2.2 Card perseveration (CP) task and slot machine simulation performance*

Despite the CP tasks specific rewarding and punishing reinforcement contingencies, no previous research has investigated explicit associations between RST brain behavioural system activity and task performance. For the other type of computerised gambling task employed, namely the slot machine simulation, previous research has tended to focus on gambling from a purely behaviour analytic perspective. It was hypothesised that higher self-reported BAS activity and Extraversion should be associated with greater response perseveration (i.e., weaker inhibitory control) on the CP task. Evidence was produced in chapter 5 to support these hypotheses. However, it should be noted that this evidence was limited to analyses involving certain groups of participants. For instance, significant evidence produced in support of the hypothesis concerning Extraversion and response perseveration was limited to correlations involving female participants on the standard task. Significant evidence produced in support of the hypothesis concerning BAS activity and response perseveration was also limited (in exploratory analyses investigating correlations separately for both sexes) to correlations involving female participants on the standard task but also to (in exploratory analyses investigating correlations separately for the two groups that performed the tasks in different orders (i.e., standard task first or pause version first)) correlations involving the standard task and participants that performed this task first (a group that comprised both females and males). Interestingly, no significant relations between Extraversion, BAS measures and response perseveration were revealed on the pause version of the task, indicating that the 5-s forced pause following response feedback on this task had the effect of weakening associations between higher self-reported BAS activity, Extraversion and greater response perseveration (revealed in the groups mentioned above). Also, the revelation that significant relations between BAS measures and response perseveration were only obtained on the standard task for participants that performed this task first indicates that the 5-s forced pause following response feedback on the pause version not only resulted in a weaker association between self-reported BAS activity and response perseveration on this task but also that it had a lasting effect on these associations if this pause version was performed before the standard task.

Due to the specific rewarding and punishing reinforcement contingencies present on the slot machine simulations it was hypothesised that higher self-reported BAS activity and Extraversion should be associated with more risky gambling behaviour (i.e., weaker inhibitory control). However, no significant evidence was produced in support of these hypotheses on either simulation (chapter 5). In fact, exploratory analyses produced evidence indicating that a higher BAS activity was related to less risky gambling behaviour on the simulation with low percentage payback rate for female participants. The study presented in chapter 7 demonstrated the influence of reinforcement expectancies on associations between self-reported BAS/Extraversion and inhibitory control on the stop-signal task. It is possible that failure to assess reinforcement expectancies and to analyse data in light of them in chapter 5 may have been responsible for the apparent lack of significant evidence in support of the hypothesis concerning Extraversion and slot machine simulation performance as well as for the unexpected evidence in contradiction to the hypothesis concerning BAS activity and slot machine simulation performance. The apparently theoretically inconsistent relationships could have been due to participants, particularly females, perceiving playing the slot machine simulations as less rewarding than initially expected. The idea was that participants would be exposed to a high level of reward initially on the slot machine simulation in the first condition (high payback rate), thus activating the BAS and resulting in more risky gambling behaviour (i.e., a greater number of maximum bets placed and so a higher total number of credits bet) and that this risky gambling behaviour would then continue for highly BAS reactive and Extraverted participants on the slot machine simulation in the second condition (low payback rate) despite the low level of reward. However, if highly BAS reactive and Extraverted participants found the simulation with high payback rate less rewarding than initially expected for one reason or another, then this could have elicited frustrative non-reward (aversive motivation) for these participants (see Corr 2002a; demonstrated on the Reward and Conflict stop-signal tasks in chapter 7). Being presented with yet another slot machine simulation (low payback rate) would then most likely heighten the aversive motivation, leading to the apparently theoretically inconsistent relationships obtained on this second simulation. Beyond the scope of this thesis, further investigation assessing reinforcement expectancies in relation to the slot machine simulations is thus necessary in order to examine further hypotheses concerning BAS activity, Extraversion, and gambling behaviour on the two simulations.

In previous research, response perseveration on the CP task has been explained in terms of Newman and Wallace's (1993) 'reward dominance' personality dimension. It has been suggested that greater reward dominance results in a reduced tendency to interrupt goal-directed behaviour to evaluate its potential negative consequences, leading to response preservation. Reward dominance can be explained in the context of RST as a heightened BAS activity and a suppressed BIS activity (see Gray, 1991). The results obtained in chapter 5 (discussed above and, in more detail in chapter 5, section 5.4.1) suggest that a heightened BAS activity was related to greater response perseveration on the standard task for females and for participants that performed this task before the pause version, and that by forcing participants to pause for 5-s following response feedback on the CP task (thus forcing them to interrupt goal-directed behaviour) heightened BAS activity was no longer associated with greater response perseveration. However, as discussed below (and in section 5.4.1 of chapter 5), the results obtained concerning associations between BIS activity and response perseveration were not consistent with a reward dominance (i.e., a heightened BAS and a suppressed BIS) explanation.

It was hypothesised that higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with lesser response perseveration. Contrary to hypotheses, however, evidence was produced in chapter 5 to suggest that higher self-reported BIS activity, FFFS activity, and Neuroticism were actually related to greater response perseveration on the standard task. However, it should be noted that exploratory analyses in this experimental chapter revealed that these unexpected associations were not present in certain groups of participants. For instance, significant evidence produced in contradiction to the hypothesis concerning FFFS activity and response perseveration was limited to correlations involving male participants on the standard task. Significant evidence produced in contradiction to hypotheses concerning BIS activity, Neuroticism, and response perseveration was limited (in exploratory analyses investigating correlations separately for both sexes) to correlations involving male participants on the standard task but also to (in exploratory analyses investigating correlations separately for the two groups that performed the tasks in different orders (i.e., standard task first or pause version first)) correlations involving the standard task and participants that performed this task after the pause version.

A similar pattern of unexpected findings concerning associations between self-reported BIS activity, Neuroticism, and task performance was produced when analysing slot machine simulation data in chapter 5. It was hypothesised that higher self-reported BIS activity, FFFS activity, and Neuroticism should be associated with less risky gambling behaviour. However, no significant evidence was produced in support of the hypothesis concerning FFFS activity and gambling behaviour on either simulation and evidence was produced to suggest that higher self-reported BIS activity and Neuroticism were actually related to more risky gambling behaviour on the simulation with low percentage payback rate. Consistent with findings concerning these personality measures and response perseveration on the standard CP task (discussed above), exploratory analyses revealed that these unexpected associations were present in the male group of participants only on this slot machine simulation.

Possible reasons for the unexpected findings concerning associations between self-reported BIS activity and performance on the standard CP task and on the slot machine simulation with low percentage payback rate were discussed in detail, within the context of revised RST (McNaughton & Corr, 2004, 2008), in section 5.4.3 of chapter 5. These findings, although unexpected, actually appear to make sense in light of the findings produced concerning pathological gamblers' personality (in an almost entirely male PG sample) in chapter 6 (discussed in detail in chapter 6, section 6.4.1; outlined below in section 8.3.1). Since pathological gamblers were found to score higher than controls on measures of BIS, FFFS, and Neuroticism, it follows that these personality measures should correlate positively with greater response perseveration/riskier gambling behaviour on the computerised gambling tasks.

It is, however, worth noting that the unexpected associations between BIS activity, FFFS activity, Neuroticism, and CP task response perseveration discussed above were observed on the standard task only. On the pause version of the task, more theoretically consistent associations between BIS activity/Neuroticism and response perseveration were observed. In fact, on the CP task with forced pause, evidence was produced in support of hypotheses that higher self-reported BIS activity and Neuroticism should be associated with lesser response perseveration. However, significant evidence produced on this task in support of these hypotheses was limited (in exploratory analyses investigating correlations separately for both sexes) again to correlations involving male participants but also to (in exploratory analyses investigating correlations separately for the two groups that performed the tasks in different orders (i.e., standard task first or pause version first)) correlations involving participants that performed the standard task first (a group that comprised both females and males). While the results obtained on the standard version of the CP task and on slot machine simulation with low payback rate suggest that high BIS and Neuroticism might have been associated with 'chasing' (i.e., trying to gain back money that was lost before) losses on these tasks – and if this was indeed the case, it appears that this 'chasing' behaviour on these tasks may reflect a heightened sensitivity to the conflict between reward and punishment (i.e., high BIS activity), expressed through approach, rather than inhibited behaviour (see chapter 5, section 5.4.3, for further explanation) – the results obtained on the pause version of the CP task suggest that the presence of a 5-s forced pause between trials resulted in high BIS activity and Neuroticism being associated with more inhibited behaviour on this gambling task (depending on gender and task order). It could be valuable to investigate whether these same effects could be obtained on the slot machine simulations simply by modifying them so that a 5-s forced pause is imposed between trials. This is perhaps an issue that could be pursued in future research.

### *8.2.3 Q-task performance*

It was hypothesised that higher self-reported BIS activity should be associated with greater behavioural inhibition on the Q-task. This hypothesis was substantiated by evidence produced in chapter 4; higher self-reported BIS activity (assessed by the BIS scale of the BIS/BAS Scales) was associated with greater Q-inhibition (the degree to which the Q elicits behavioural inhibition in the test phase). Newman et al. (1997), with the use of the trait form of the STAI (Spielberger et al., 1970), demonstrated in a sample of undergraduate students that Anx+ (i.e., high BIS) participants responded more slowly than Anx- (i.e., low BIS) participants on Q-present versus Q-absent trials. Rather than splitting participants into groups (e.g., Anx+/Anx-) based on their scores on personality measures, personality data was kept continuous for analyses concerning the Q-task in chapter 4. The results obtained from the correlational analyses of these continuous data provided further support for the reputation of the Q-task as a face valid, behavioural assessment device for the measurement of BIS functioning (see Pickering et al., 1997).

## 8.3 Gambling, personality, inhibitory control, reinforcement, and behavioural inhibition

### *8.3.1 Pathological gamblers' self-reported sensitivity to reward/punishment*

At the time of writing the introduction to this thesis (chapter 1), no previous research had investigated explicit links between RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity and pathological gambling (PG). Strong evidence had, however, related impulsivity (proposed to be linked to the BAS; see Corr, 2004) to PG (see chapter 1, section 1.3.1), leading to the suggestion in the present thesis that, within the context of RST, the disinhibited behaviour characterised by PG may result from hyper-sensitivity to reward. This led to the hypothesis that pathological gamblers should be more highly BAS reactive than non-problem gamblers. Significant evidence was produced in support of this hypothesis (chapter 6) based on mean scores on the Sensitivity to Reward scale (BAS measure) of the SPSRQ. Thus, it could be suggested that the disinhibited behaviour characterised by PG may indeed result from a more reward sensitive personality. Since gambling not only presents potential reward but also potential punishment (to a greater degree even than reward, particularly in the long term), it was suggested that dysfunctions of impulse control characterised by PG may also result from distortions of the FFFS and the BIS. Based on arguments in the previous literature that problem gamblers are insensitive to punishment in that they fail to cease gambling despite losses, and demonstrate a tendency to persist in gambling/performing more poorly (compared to controls) on decision-making tasks despite potential future punishment (Vitaro et al., 1999), it was hypothesised that pathological gamblers should be less highly FFFS/BIS reactive than non-problem gamblers.

However, the results obtained in chapter 6 provided evidence indicating that, as well as being more highly BAS reactive than controls (as expected), pathological gamblers were more highly BIS/FFFS reactive than controls (based on mean scores on the Sensitivity to Punishment scale (BIS measure) of the SPSRQ, the STAI (BIS measure), and FSS Fear (FFFS measure)), contrary to hypothesis. The findings suggest that pathological gamblers (vs. controls) were hyper-sensitive to punishment, running contrary to evidence that problem gamblers continue to gamble due to *in*sensitivity to punishment (Vitaro et al., 1999). Since writing the introduction to this thesis, presented in chapter 1, a number of studies in the literature have investigated explicit links between RST brain behavioural system (i.e., BIS, BAS, and FFFS) activity and problem gambling (e.g., Goudriaan et al., 2006; Loxton et al., 2008) and consistent with the findings obtained in the present thesis, Goudriaan et al. and Loxton et al. produced evidence showing that problem gamblers scored higher than normal controls on self-reported measures of both BIS and BAS activity. It is suggested in this thesis that these findings make sense within the context of Corr's (2009) and McNaughton and Corr's (2009) explanation for the development and maintenance of maladaptive gambling behaviour based on the concept of 'relief of non-punishment' (see chapter 6, section 6.4.1).

### *8.3.2 Pathological gamblers' inhibitory control and behavioural inhibition*

#### *8.3.2.1 Stop-signal task performance*

It was hypothesised that pathological gamblers should demonstrate weaker inhibitory control compared to non-problem gamblers. This hypothesis was based on growing evidence in the previous literature of the association between impaired inhibitory control and PG (see chapter 1, section 1.3.1). However, no significant evidence was obtained to suggest that pathological gamblers demonstrated weaker inhibitory control (vs. controls) across the four stop-signal tasks employed in the present thesis (chapter 6). Evidence in the previous literature of the association between impaired inhibitory control and PG has been obtained using behavioural tasks such as the go/no-go task (Goudriaan et al., 2005) and the delayed response task (Dixon et al., 2003). Since, compared to these tasks, the stop-signal paradigm would be considered a 'purer' measure of the inhibitory control process (see chapter 1, section 1.3.1), the results obtained in this thesis using this paradigm indicate against a general impairment of the inhibitory control process in pathological gamblers.

Since writing the introduction to this thesis, presented in chapter 1, several more relevant studies have appeared in the literature investigating inhibitory control in pathological gamblers using the go/no-go task (Fuentes, Tavares, Artes, & Gorenstein, 2006; Kertzman et al., 2008) and the Continuous Performance Test (CPT; Kertzman et al.; Rodriguez-Jimenez et al., 2006a). While the Fuentes et al. and Kertzman et al. studies produced findings apparently consistent with growing evidence in the previous literature of the association between impaired inhibitory control and PG using these behavioural tasks, Rodriguez-Jimenez et al. found, similar to the findings obtained in chapter 6 concerning group differences in inhibitory control across the four stop-signal tasks (discussed above), no impairment in a group of pathological gamblers using the CPT. It should be noted, however, that unlike the stop-signal tasks valid and reliable measure of the inhibition process (Kindlon et al., 1995; Logan, 1994), the CPT suffers the same criticism as the go/no-go task and the delayed response task in terms of their poor construct validity or reliability (Halperin et al., 1994; Kindlon et al., 1995; Oosterlaan et al., 1998; see chapter 1, section 1.3.1).

Importantly, however, although the results obtained in chapter 6 suggest that there was no between-group (PG vs. control) difference in response inhibition across the four stop-signal tasks, significant evidence was produced in this same chapter indicating that the effect of the different task contingencies (i.e., specific motivational stimuli) on response inhibition differed when comparing pathological gamblers with non-problem gamblers. Based on the predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was hypothesised that pathological gamblers' inhibitory control should be shown to be less strongly effected by the introduction of specific punishing stimuli to the stop-signal task (i.e., their inhibitory control should strengthen to a lesser degree) compared to non-problem gamblers' inhibitory control and that pathological gamblers' inhibitory control should be shown to be more strongly effected by the introduction of specific rewarding stimuli to the stop-signal task (i.e., their inhibitory control should weaken to a greater degree) compared to non-problem gamblers' inhibitory control.

Consistent with hypothesis, evidence was produced in chapter 6 indicating that the presence of specific rewarding stimuli alone on the Reward task was, when comparing this task with the Baseline (i.e., standard; no specific motivational stimuli) task, shown to have a stronger effect on pathological gamblers' inhibitory control compared to non-problem gamblers' inhibitory control; the PG group's probability of inhibition was found to decrease to a greater degree and their estimated time to inhibit a response (i.e., SSRT) slowed to a greater degree (i.e., the PG group's inhibitory control weakened to a greater degree) than the control group's on the Reward task compared to on the Baseline task. The presence of specific punishing stimuli alone on the Punishment task was not, when comparing this task with the Baseline (i.e., standard; no specific motivational stimuli) task, shown to have a significantly different effect on pathological gamblers' inhibitory control compared to non-problem gamblers' inhibitory control (chapter 6), contrary to hypothesis. As mentioned above, however, in terms of self-reported personality, rather than being hypo-sensitive to punishment as predicted, evidence was produced to suggest that pathological gamblers were actually more punishment sensitive than non-problem gamblers and so it seems appropriate, although contrary to hypothesis, that the presence of specific punishing stimuli on the Punishment task had just as strong an effect on pathological gamblers' inhibitory control as it had on controls'.

Near significant evidence was produced in chapter 6 indicating that the presence of the combination of both specific rewarding and punishing stimuli on the Conflict task had, when comparing this task with the Baseline (i.e., standard; no specific motivational stimuli) task, a different effect on pathological gamblers' inhibitory control (based on probability of inhibition on stop-trials alone) compared to non-problem gamblers' inhibitory control. Whereas probability of inhibition on stop-trials was similar on these two tasks for controls, probability of inhibition on stop-trials was lower (i.e., inhibitory control was weaker) on the Conflict task than on the Baseline task for pathological gamblers. Since it was hypothesised that pathological gamblers' inhibitory control should be shown to be less strongly effected by the introduction of specific punishing stimuli to the stop-signal task (i.e., their inhibitory control should strengthen to a lesser degree) compared to non-problem gamblers' inhibitory control and that pathological gamblers' inhibitory control should be shown to be more strongly effected by the introduction of specific rewarding stimuli to the stop-signal task (i.e., their inhibitory control should weaken to a greater degree) compared to non-problem gamblers' inhibitory control, this finding concerning inhibitory control on the Conflict task (specific rewarding and punishing stimuli) appears consistent with hypotheses. Other interaction effects between group (PG vs. control) and stop-signal task for measures of response inhibition (as well as response execution) were also revealed and discussed in chapter 6.

*8.3.2.2 Card perseveration (CP) task performance*

It was hypothesised that pathological gamblers should perseverate longer (i.e., demonstrate weaker inhibitory control) on the standard CP task (immediate feedback only) compared to non-problem gamblers but also that the imposition of a forced 5-s pause following immediate response feedback on the CP task should reduce pathological gamblers' relative perseverative deficit. These hypotheses were fully substantiated by evidence produced in chapter 6. The finding that pathological gamblers perseverated longer than controls on the standard task was consistent with the findings of Goudriaan et al.'s (2005) study and adds support for the link between PG and 'behavioural disinhibition' (McCormick, 1993). Newman et al. (1987) demonstrated that while psychopaths (another group, like pathological gamblers, characterised by disinhibited behaviour) perseverated to a greater degree than non-psychopaths on the standard task, this relative perseverative deficit was reduced on the task with a cumulative feedback display accompanied by a 5-s waiting period during which participants were prevented from making another response. In accordance with these findings, the results obtained in chapter 6 demonstrated that a forced 5-s pause following response feedback (immediate only, as opposed to the cumulative display used in Newman et al.'s study) effectively reduced pathological gamblers' relative perseverative deficit. As discussed in section 6.4.4 of chapter 6 and in section 8.5 below, this finding could have potentially valuable implications for informing practice in the treatment of PG as well as for the development of proposals for modifying the gambling environment in order to reduce the development of problematic gambling behaviour.

*8.3.2.3 Slot machine simulation performance*

Based on predictions that pathological gamblers should be hypo-sensitive to punishment and hyper-sensitive to reward, it was hypothesised that pathological gamblers should demonstrate more risky gambling behaviour (i.e., weaker inhibitory control) across the slot machine simulations compared to non-problem gamblers and that pathological gamblers' slot machine simulation gambling behaviour should be less strongly effected by a reduction in percentage payback rate (i.e., an increase in the probability of being presented with a punishing trial should be less effective in moderating pathological gamblers' risky gambling behaviour) compared to non-problem gamblers' slot machine simulation gambling behaviour. Evidence was produced in support of these hypotheses in chapter 6; results indicated that, although, overall, a lower total number of credits were bet on the slot machine simulation with low percentage payback rate than on the simulation with high percentage payback rate, this simulation effect was shown to be weaker for the PG group than for the control group and, overall, the PG group were found to bet a higher total number of credits (indicating more risky gambling behaviour) than the control group across the two simulations. Due to the fact that, contrary to prediction, in terms of self-reported personality, pathological gamblers were not found to be hypo-sensitive to punishment but, rather, they were in fact more punishment sensitive than controls, this would suggest that pathological gamblers were perseverating for reward to a greater degree (in terms of personality, the PG group were shown to be more reward sensitive) than the control group on the simulation with low percentage payback rate, similar to the way in which they performed the standard CP task (discussed above). As discussed in section 6.4.4 of chapter 6 and in section 8.5 below, the results obtained concerning response perseveration on the two CP tasks have potential implications for reducing this type of maladaptive behaviour on other gambling tasks such as slot machines.

*8.3.2.4 Q-task performance*

The Q-task was used to assess behavioural inhibition in pathological gamblers compared to non-problem gamblers (chapter 6). Using this task, no significant evidence was produced in support of the hypothesis that pathological gamblers should demonstrate less behavioural inhibition compared to non-problem gamblers. Newman et al. (1997) validated the Q-tasks assessment of behavioural inhibition by demonstrating that psychopaths (a clinical group characterised by disinhibited behaviour) display less inhibition than non-psychopathic controls on Q-present trials, consistent with weak BIS models of psychopathy (e.g., Fowles, 1980; Gray, 1987). Since PG has been linked to 'behavioural disinhibition' (McCormick, 1993), and it was predicted that pathological gamblers should be less punishment sensitive (i.e., weaker BIS) than controls, it was anticipated that, similar to Newman et al.'s psychopaths, pathological gamblers should display less inhibition than controls on Q-present trials. In fact, although not significant, mean differences in Q-inhibition (the degree to which the Q elicits behavioural inhibition in the test phase) indicate that the PG group displayed slightly greater inhibition on Q-present trials than the control group.

However, as discussed above and in section 6.4 of chapter 6, pathological gamblers were actually more highly BIS reactive (according to mean scores on the Sensitivity to Punishment scale of the SPSRQ and the STAI) than controls and did not display disinhibited behaviour (vs. controls) on the standard stop-signal task either. Thus the lack of evidence in support of the hypothesis that pathological gamblers should demonstrate less behavioural inhibition compared to non-problem gamblers on the Q-task, although unexpected, was consistent with some of the other unexpected findings revealed in this investigation. The Q-task was designed as a measure of BIS activity and, although not significant, the group with the higher self-reported BIS activity (i.e., the PG group) displayed slightly greater inhibition on Q-present trials than the group with the lower self-reported BIS activity (i.e., the control group), thus almost providing further support for the Q-tasks reputation as a face valid, behavioural assessment device for the measurement of BIS functioning (see Pickering et al., 1997). As mentioned in section 6.4.3 of chapter 6, Newman et al's (1997) findings concerning psychopaths' significantly different Q-inhibition to non-psychopathic controls' was limited to comparisons involving Anx+ (i.e., high BIS) participants. It is possible, therefore, that had the PG group and the control group been divided into Anx+ pathological gamblers and Anx+ controls, the between-group difference in mean Q-inhibition might have reached significance. This provides a possible avenue for future research into PG and inhibition on the Q-task.

The limitations of this thesis will now be discussed.

**8.4 Limitations**

Several limitations of the studies presented in this thesis warrant consideration. First, the gambling related tasks employed (i.e., the card perseveration tasks and slot machine simulations), unlike real commercial gambling machines/games, lacked monetary rewards/punishments. Clearly greater ecological validity would have been achieved with the use of monetary task contingencies, providing participants with the opportunity to win, lose, and keep real cash winnings. Unfortunately, however, due to limited financial resources, this was not a viable option for the studies in the present thesis and, instead, participants were informed that their winnings from each of the tasks would be compared with the average individual's winnings and that, therefore, they should try to finish with as much 'cash' (on the card perseveration tasks) or 'credits' (on the slot machine simulations) as possible. It was anticipated that, although participants were not playing for real money, by informing them of the above, they would be sufficiently motivated to view the tasks, as well as the cash/credits, seriously. Although most of the results obtained concerning task and group differences in performance of these tasks (see chapters 5 and 6) suggest that this was indeed an effective method of motivation, since despite the absence of monetary contingencies participants performed the tasks significantly differently and consistent with hypotheses (except when comparing mean response latencies between groups), it is possible that participants may evaluate wins and losses on these tasks differentially when playing with monetary contingencies compared to the 'cash' and 'credits' used in the present thesis. This is perhaps an issue for future research to investigate.

Experimental studies presented in chapters 4 and 5 would have benefited from assessing levels of reinforcement expectancies in relation to the behavioural tasks employed. The omission of these assessments limited the validity of the data collected to test hypotheses concerning associations between self-reported sensitivity to reward/punishment and task performance (as indicated by the findings in chapter 7), since it was not clear for whom manipulations of motivation (rewarding and punishing) on the stop-signal task were actually effective or for whom the 'cash'/credits available to bet with on the CP tasks/slot machine simulations was sufficiently important to be rewarding/punishing when won/lost on these tasks. It would be vital for future studies to make these important assessments (possibly using methodology similar to that employed in chapter 7) in order to overcome this particular limitation of the present thesis.

An issue considered briefly in chapter 6 (section 6.4.6) was that the use of a predominantly male pathological gambling sample (most probably because PG occurs more frequently in males, and thus more male pathological gamblers were present and recruited in the betting shop), all of whom were recruited from a single betting shop (i.e., bookmakers) in Swansea, limits the generalisibility of the findings concerning PG, personality and inhibitory control beyond this gender and select gambling type. Gender and cross-cultural differences in PG and differences in the behaviour of gamblers that pursue different types of gambling have been documented in the previous literature (Goudriaan et al., 2005; Raylu & Oei, 2002). While, overall, Goudriaan et al. demonstrated decision making problems in a sample of pathological gamblers using the Iowa Gambling Task (IGT), the go/no-go task, and an adapted version of the CP task, the authors noted that part of the PG sample showed task performance resembling that of the control group (i.e., normal task performance/decision making); a finding consistent with studies reporting that subgroups of substance abusers showed 'normal' IGT performance (whilst others showed poor performance; Bechara et al., 2001; Bechara, Dolan, & Hindes, 2002; Bechara & Martin, 2004). This could explain the lack of evidence demonstrating pathological gamblers' impaired inhibitory control across the four stop-signal tasks and lesser behavioural inhibition on the Q-task (as well as other unsupported predictions concerning the PG group in chapter 6). It is possible that evidence may have been produced in support of these hypotheses had pathological gamblers been divided into subgroups for analyses. Furthermore, response perseveration on the CP task and slot machine simulation may have been shown to be even greater in subgroups of pathological gamblers while, on the other hand, performance on these tasks may have been shown to resemble that of controls' in certain subgroups. It is, therefore, recommended that future studies in this area of research should recruit pathological gamblers from a more diverse population and include more females, whilst ensuring to investigate differences between subgroups within such broad samples, in order to overcome this particular limitation of the present thesis.

The methodology employed to accurately identify pathological gamblers in the present thesis might have been limited due to its exclusive reliance upon the SOGS. Although the SOGS is the most widely used diagnostic tool in research studies for identifying pathological gamblers (Walker & Dickerson, 1996), its reliability and validity has been criticised (Raylu & Oei, 2002). For example, a number of studies have indicated the possibility of obtaining high false-positives in general population surveys when utilising the SOGS for identification of pathological gamblers (Abbott & Volberg, 1992; Dickerson, 1993). Although the PG group was not recruited from the general population (they were recruited from a betting shop to ensure recruitment of an adequate sized sample within the time-frame allowed), it is possible the sample comprised a high proportion of false-positives (i.e., participants inaccurately identified as pathological gamblers) due to reliance upon SOGS diagnosis criteria. The presence of these inaccurately identified PG participants would confound the findings concerning PG, personality and inhibitory control and could explain the lack of evidence demonstrating the PG group's impaired inhibitory control across the four stop-signal tasks and lesser behavioural inhibition on the Q-task (as well as other unsupported predictions concerning the PG group in chapter 6).

However, criticism aside, the SOGS has demonstrated satisfactory validity and reliability both in gambling treatment samples and in the general population (e.g., Stinchfield, 2002), it has been validated by cross-tabulating scores with both family members' assessments and counsellors' individual ratings and SOGS scores have correlated strongly with *DSM-IV* (APA, 1994) items for PG. The SOGS was, however, developed in a clinical setting and the PG group included in the present thesis was not recruited from this type of setting (e.g., outpatients of a gambling treatment clinic) since such a methodology would have further restricted generalisation of the findings to the general PG population (such a sample could represent a group of pathological gamblers that experienced more severe gambling problems and greater response perseveration in real life, and subsequently sought treatment from a clinic). This thesis may have benefited from using a measure developed to assess PG among the general public (e.g., the Canadian Problem Gambling Index; CPGI; Ferris, Wynne, & Single, 1999) alongside the SOGS, in an attempt to yield a more reliably identified group of pathological gamblers. Where possible, this would be desirable for future research.

Although the effects of demographics such as age and sex, as well as other potential confounding extraneous variables such as order of task administration, were, where possible and appropriate, investigated (and controlled for, where appropriate) within the studies presented in this thesis, the effects of IQ on task performance were not assessed. It is understood that IQ is not an influencing factor on stop-signal task performance (Kindlon et al., 1995), evidence has been produced to suggest the same on the CP task (Fisher & Blair, 1998), and previous studies employing the Q-task appear not to have viewed IQ as a potentially important influencing factor to control for (since IQ has not been assessed in these studies; e.g., Newman et al., 1997; Kambouropoulos & Staiger, 2004). However, for the other type of behavioural task employed in this thesis, the slot machine simulation, it seems possible that IQ may have influenced performance. Optimum performance across the two slot machine simulations (i.e., finishing the two simulations with the highest possible number of credits) required adopting a particular type of strategy. This optimum strategy involved placing mostly maximum bets on the simulation with high percentage payback rate (the first simulation administered) in order to maximise overall wins on this slot machine and then placing minimum bets on the vast majority of trials on the simulation with low percentage payback rate (the second simulation administered) in order to minimise overall loss on this slot machine. It is likely that IQ may have had an influence on participants' ability to recognise the benefits of adopting such a performance strategy and, therefore, results obtained may be confounded due to this uncontrolled factor. Had IQ been controlled for in analyses involving slot machine simulation performance (chapters 5 and 6) perhaps evidence would have been produced to support hypotheses concerning associations between BAS activity, Extraversion, and total number of credits bet on the simulations in chapter 5 and/or simulation effects may not have been shown to be different between groups (PG vs. control) for this same dependent variable in chapter 6. Thus, where possible, it would be desirable for future research to assess IQ in relation to task performance.

Any investigation dealing with results based on self-reported responses to questionnaire items is prone to the possibility that responses given may not be truthful (i.e., social desirability bias). The results obtained would have been confounded if some participants were not completely honest when completing the SOGS and/or the other psychometric measures of personality. It was vital that participants were truthful for valid results concerning personality to be obtained, and steps were taken to control for this possible confounding variable. EPQ-RS Lie scale scores were included in all correlational analyses and controlled for, where appropriate, since this scale is designed to measure the tendency to be untruthful. This of course does not necessarily mean that people were not untruthful in their responses and there is still the possibility that the data obtained may not be valid as a result. Another possible limitation resulting from the manner in which self-report gambling/personality data was collected could be that these psychometric measures are only suitable for certain types of participant – those who are literate and willing to spend time filling in a questionnaire. This of course creates a biased sample. However, this is an issue that all studies employing self-report questionnaire methodology (i.e., almost all studies investigating personality) must take into consideration. Finally, a number of experimental studies would have benefited from larger participant groups. This would have improved statistical power and reliability of results.

### 8.5 Implications and future directions

Data obtained from the studies in this thesis have implications as well as providing (along with the behavioural tasks developed) various avenues for extending research in the investigation of inhibitory control, reinforcement, personality, and gambling behaviour. Findings concerning associations between personality and task performance in chapters 4, 5, and 7 have implications for any study employing Gray's RST to investigate reactions to rewarding and punishing situations: it is necessary that any such study assesses reinforcement expectancies in relation to the rewarding/punishing situations to ensure that manipulations of motivation are effective. The pattern of results produced in these experimental chapters indicated that, in accordance with the findings of Kambouropoulos and Staiger's (2004) study:

> If participants perceive a presumed appetitive task as less rewarding than initially expected, theoretically inconsistent associations between self-report measures of BIS/BAS and actual responses to reward will most likely be observed. In contrast, when . . . [a presumed appetitive task] was perceived to be rewarding, thereby representing an adequate input to the BAS, more theoretically consistent relationships between reward responsivity and self-report BIS/BAS measures were found. (p. 1163)

However, the influence of reinforcement expectancies was only investigated in relation to associations between self-reported BAS/Extraversion and inhibitory control on the two stop-signal tasks with specific rewarding stimuli present (the Reward and Conflict tasks; chapter 7). Due to the success of these investigations in providing data appearing to explain some of the unexpected findings obtained concerning these particular associations in chapter 4, it was assumed that unexpected findings concerning associations between BIS/FFFS/Neuroticism and task performance obtained in chapters 4 and 5 could most likely also be explained in terms of having neglected to assess the influence of reinforcement expectancies. Future research could be carried out to help to confirm that these were indeed valid assumptions and thus confirm the role of reinforcement expectancies in producing theoretically consistent associations between BIS/FFFS activity and punishment responsivity (just as the findings of this thesis confirmed the role of reinforcement expectancies in producing theoretically consistent associations between BAS activity/Extraversion and reward responsivity on the stop-signal task).

Another potential avenue for future research would be to investigate whether the BIS and BAS systems interact to produce behavioural outcomes ('joint subsystems hypothesis'; Corr, 2001) on the tasks employed in this thesis. The separable subsystems hypothesis (Corr, 2001, 2002b), which postulates that the BIS and BAS are separate systems independent of one another in their effects, was the approach adopted for use in this thesis since it is the perspective most common among RST studies. However, in an attempt to account for the diversity of findings from RST studies in the literature, Corr (2001, p. 514) 'proposed a revision of RST to take into account the mutual interplay of BIS and BAS effects'. Given the diversity of findings from the experimental studies investigating RST in relation to task performance in this thesis, future studies applying this joint subsystems hypothesis approach may be beneficial in shedding light on some of the more unexpected findings obtained. Experimental situations in which effects consistent with the separable subsystems hypothesis should be observed are predicted to be those 'that do not contain mixed reward and punishment cues, or demand rapid attentional and behavioural shifts between these two sets of motivational cues' (Corr, 2001, p. 514). It could be argued that each of the behavioural tasks employed contained mixed reward and punishment cues, even the stop-signal task with no specific motivational stimuli (standard/Baseline task) and those with specific rewarding (Reward task) or punishing (Punishment task) stimuli only since even without specific motivational stimuli the go-signal may be interpreted 'as a reward and goal-directed cue that triggers an approach response, and the stop signal as a punishment cue associated with response inhibition' (Avila & Parcet, 2001, p. 983), and the stop-signal task certainly demands 'rapid attentional and behavioural shifts between these two sets of motivational cues' (Corr, 2001, p. 514). Thus future research may prove these tasks to be better test-beds for the joint subsystems hypothesis.

Yet another potential avenue for future research would be to investigate the influence of arousal on associations between self-reported sensitivity to reward/punishment and performance on the tasks employed in this thesis, since it is possible for level of arousal to effect behaviour motivated by rewarding/punishing stimuli. According to Gray's model, although arousal level 'should not alter the basic pattern of reinforcement effects, it may alter the intensity of behaviour' (Corr, 2002b, p. 523). Corr suggests that 'Arousal effects might be especially important on tasks where there are opposing motivational tendencies of (1) withholding (punishment-mediated) responses, and (2) greater (arousal-mediated) behavioural intensity' (p. 530). Since the stop-signal task involves rapid response to 'go' stimuli (rewarded) and withheld responses in the presence of stop-signals (otherwise punished) it may be valuable to examine effects of level of arousal on these tasks at least. Any future study taking on this line of investigation could manipulate arousal in a similar manner to that described in Corr's study (i.e., 500 mg caffeine citrate vs. placebo). Corr found theoretically consistent results concerning the joint subsystems hypothesis and disinhibition 'only in the caffeine group, suggesting that high levels of arousal may be necessary for the invigoration of disinhibitory behaviour' (p. 511).

The findings obtained on the CP tasks (chapters 5 and 6) have potentially valuable implications for informing practice in the treatment of PG as well as for the development of proposals for modifying the gambling environment in order to reduce the development of problematic gambling behaviour (see section 6.4.4 of chapter 6 for a more detailed discussion of these implications including examples of how they might be applied). Research producing implications such as these has become especially important in the UK since the most recently amended legislation of gambling activity in this country (Gambling Act 2005). This change in legislation has greatly increased society's opportunity to participate in gambling behaviour and, therefore, could possibly lead to an increased prevalence of problem gambling and thus a greater number of individuals experiencing gambling related problems. Future research could impose a 5-s waiting period following response feedback on slot machine simulations and/or video poker simulations to investigate whether similar effects to those observed on the CP tasks in the present thesis could be obtained on other types of computerised gambling tasks.

Evidence was produced in this thesis to suggest that participants' mean response latency was found to be faster following losses than it was following wins on the CP task (chapter 5), and a similar pattern of results were observed on the slot machine simulations in this thesis (chapter 5) as well as on other computerised (as well as on real commercial) slot machines (Dixon & Schreiber, 2004; Schreiber & Dixon, 2001) and on video poker simulations (Dixon & Schreiber, 2002) in previous research. Failure to pause following punishment has been shown to be related to poorer learning from punished errors (Patterson et al., 1987). Therefore, it seems likely that increasing the time period between bet outcome and initiation of another bet on these other types of gambling tasks should moderate maladaptive gambling behaviour in a similar manner to that demonstrated on the pause version of the CP task. Future research devoted to this avenue of investigation could produce further data with valuable implications for modifying the gambling environment in order to reduce the development of problematic gambling behaviour.

Results were obtained concerning PG and personality that have implications for understanding and explaining the development and maintenance of maladaptive gambling behaviour within the context of RST (see section 6.4.1 of chapter 6 for an in-depth discussion of these implications). Personality dispositions defined by the combination of an abnormally high BAS activity (indicating a hyper-sensitivity to reward) as well as an abnormally high BIS/FFFS activity (indicating a hyper-sensitivity to punishment) could play a role in the development and/or maintenance of PG. Longitudinal studies could shed light on the causal relation between abnormal reward/punishment sensitivity and PG, for instance by including a group of social gamblers who do not exhibit gambling problems, and a sub-clinical PG group, and assess which personality dispositions appear to lead to the development of PG over time. Given the promising theoretical framework provided by RST for understanding the motivational dynamics underlying PG, the more research that focuses on investigating links between BIS/BAS/FFFS activity and PG in the future the better.

Psychometric measures of personality were used to compare self-reported sensitivity to reward/punishment (i.e., BIS/BAS/FFFS activity) in pathological gamblers vs. non-problem gambling controls (chapter 6). However, although mean scores on a number of these measures differentiated the PG group from the control group (see section 6.3.1 of chapter 6), direct associations between personality and performance on the behavioural tasks were not examined in the PG group. In order to understand the precise nature of the association between sensitivity to reward/punishment (i.e., BIS/BAS/FFFS activity) in pathological gamblers and inhibitory control on the various different behavioural tasks employed in this thesis, future research should be directed at correlating these variables. It would be important, however, based on the findings of chapter 7, for any such future research to analyse the data in light of levels of reinforcement expectancies in relation to the tasks.

Future research investigating inhibitory control on the stop-signal task in the presence of different specific motivational stimuli could adapt the three modified versions of the standard task developed in this thesis (i.e., the Punishment, Reward and Conflict tasks) so that the rewarding/punishing contingencies are monetary rather than points-based. For example, on the Punishment and Conflict tasks the text "POOR! You lose 10 points!" appearing as part of the specific punishing stimuli following response errors and lack of inhibition could be replaced with "POOR! You lose 10 pence!", and on the Reward and Conflict tasks the text "GOOD! You win 10 points!" appearing as part of the specific rewarding stimuli following speeded responses could be replaced with "GOOD! You win 10 pence!". Participants could be staked with a certain amount of money at the beginning of each of the tasks (e.g., £5), informed that money would be added/subtracted from this amount based on their task performance, and told that they would be allowed to keep the final amount on completion of the tasks. This could be a particularly valuable approach to adopt in future research investigating pathological gamblers' inhibitory control on the stop-signal task since modifications in inhibitory control across tasks could be explained more validly within the context of gambling behaviour. Rodriguez-Fornells et al.'s (2002) study investigating inhibitory control and the personality trait of impulsivity used a task which involved monetary rewarding/punishing response contingencies; participants were staked with $5 at the beginning of the second (approach-avoidance conflict situation) session and won and lost points (which then translated into additions/subtractions of 3 cents per win/loss to/from the initial $5 stake) depending on their task performance. However, Rodriguez-Fornells et al. did not assess reinforcement expectancies in relation to their adapted version of the stop-signal task. As indicated by the findings of this thesis (chapter 7), it would be important for these assessments to be made in any future study attempting to use adapted tasks (such as those described above) to investigate associations between personality and inhibitory control.

## Conclusions

Evidence produced in this thesis indicates that inhibitory control (as measured by the stop-signal paradigm) can indeed be modified using different specific motivational stimuli (i.e., reinforcement). Certainly this was not an entirely original finding; Oosterlaan and Sergeant (1997) and Rodriguez-Fornells et al. (2002) opened the door into this new and exciting area of research. However, both of these previous attempts to design and implement tasks with specific rewarding and punishing contingencies were limited in certain important ways (see chapter 1, section 1.1.1.1). These limitations were overcome in the methodology employed in this thesis, and four unique stop-signal tasks, having been developed specifically for the purposes of this thesis (and shown to be valid and reliable measures of the inhibition process across numerous studies), produced evidence indicating that, as predicted: the introduction of specific punishing stimuli associated with response errors (including not stopping for stop-signals) resulted in an increased care in task performance and, consequently, stronger inhibitory control on the task; the introduction of specific rewarding stimuli associated with speeded responses to the go-signal resulted in an increased motivation in approaching this go-signal and, consequently, weaker inhibitory control on the task; and the introduction of the combination of both specific punishing and specific rewarding stimuli (thus creating an approach-avoidance conflict situation) resulted in similar inhibitory control on the task (compared to on the standard task). Thus the development and implementation of these tasks has not only contributed to knowledge of inhibitory control on the stop-signal paradigm but has also provided investigative tools for future research purposes.

This thesis demonstrated that a forced 5-s waiting period alone (following immediate response feedback) reduced response perseveration (i.e., strengthened inhibitory control) on the CP task. In a previous study, Newman et al. (1987) demonstrated a similar effect on this task by imposing a forced 5-s waiting period accompanied by a cumulative feedback display. Where Newman et al.'s study left it unclear as to whether or not this effect was due to the forced 5-s waiting period alone or the combination of the waiting period together with the cumulative feedback display, the results obtained in the present thesis clearly indicate that perseveration was reduced through forcing participants to pause following response feedback even without the presence of a cumulative display of information about the changing probability of punishment. This was an important finding within the context of gambling research since most gambling machines/games/activities do not provide a cumulative feedback display, and so the revelation that the presence of such a display is not an essential accompaniment to a forced waiting period in order for response perseveration to be reduced on the CP task indicates the potential for moderating real world gambling behaviour simply by increasing the time period between bet outcome and initiation of another bet.

Evidence produced in this thesis clearly demonstrated that gambling behaviour varied as a function of percentage payback (i.e., overall rate of reinforcement) on computerised slot machine simulations. It had previously been concluded in a study conducted by Weatherly and Brandt (2004) that credit value (i.e., reinforcer magnitude) effected gambling behaviour but that 'gambling behavior [on computerised slot machine simulations] did not vary as a function of payback percentage' (p. 33). The results obtained in this thesis suggest that gambling behaviour on computerised slot machine simulations can vary as a function of percentage payback rate, so long as sufficiently varied rates are employed; participants bet a lower total number of credits on the simulation with low percentage payback rate (30%) than on the simulation with high percentage payback rate (70%), indicating that the high rate of punishment on the simulation with low percentage payback rate resulted in more cautious gambling behaviour, in an attempt to minimise overall loss. Thus the development and implementation of these simulations has not only contributed to the limited amount of previous research demonstrating that gambling behaviour can be studied empirically in a laboratory setting using these ecologically valid gambling tasks but has also provided investigative tools for expanding this field of research in future studies.

Evidence was produced to suggest that self-reported personality was associated with performance on each of the behavioural tasks employed, although in certain cases this evidence was limited to analyses involving one gender and/or one particular task order. While some of this evidence indicated theoretically consistent associations (e.g., higher BIS activity being associated with greater behavioural inhibition on the Q-task), many unexpected associations were obtained; possibly due to methodological issues. Importantly, some of these unexpected findings were followed-up in further investigation and as a result evidence was produced indicating the importance of assessing reinforcement expectancies in relation to behavioural tasks in order to produce theoretically consistent relationships between presumed appetitive/aversive situations and self-reported sensitivity to reward/punishment – a finding which has valuable implications for any study employing Gray's RST to investigate reactions to rewarding and punishing situations. However, further research is recommended in order to investigate specifically some of the other discrepancies observed concerning expected relationships between personality measures and task performance.

Pathological gamblers were shown to score higher than non-problem gambling controls on self-report measures of BAS, BIS and FFFS, indicating that pathological gamblers were hyper-sensitive to reward as well as to punishment. The latter of these findings (pathological gamblers' apparent hyper-sensitivity to punishment), although unexpected and contrary to prediction, was consistent with the findings of other recent studies (Goudriaan et al., 2006; Loxton et al., 2008) investigating RST and problem gambling, appearing in the literature since the introduction to this thesis (chapter 1) was put together. It is suggested in this thesis that these findings make sense within the context of Corr's (2009) and McNaughton and Corr's (2009) recent alternative explanation for, and thus have implications for understanding and explaining, the development and maintenance of maladaptive gambling behaviour based on the concept of 'relief of non-punishment'.

Mixed support was produced for the growing evidence in the literature of the association between impaired inhibitory control and PG. Overall, the results obtained indicate that pathological gamblers did not demonstrate general inhibitory deficits (assessed by the standard stop-signal task and the Q-task; tasks which have not previously been utilised for the investigation of inhibitory control and PG), but that they were shown to demonstrate deficient inhibitory control (vs. non-problem gambling controls) on tasks with specific rewarding contingencies. It seems that pathological gamblers (vs. controls) were more influenced by, and perseverated to a greater degree for, specific rewarding stimuli on the behavioural tasks when such stimuli was contingent (as it is in any real world gambling situation). Since this investigation was the first of its kind to utilise the stop-signal paradigm and the Q-task for examination of inhibitory control and behavioural inhibition in pathological gamblers, the data obtained provide original contributions to knowledge surrounding inhibitory control and PG.

The findings obtained on the CP tasks have implications for reducing the apparent greater influence of (and thus the greater perseveration for) specific rewarding stimuli on pathological gamblers' behaviour. While pathological gamblers were shown to perseverate longer than controls on the standard CP task, a finding consistent with previous research (Goudriaan et al., 2005), the imposition of a forced 5-s pause following response feedback was shown to reduce this relative perseverative deficit. This latter finding was an original one, and one that could have potentially valuable implications for informing practice in the treatment of PG as well as for the development of proposals for modifying the gambling environment in order to reduce the development of problematic gambling behaviour.

Overall, it is hoped that studies in this thesis increase knowledge and understanding of inhibitory control; reinforcement; personality; and gambling behaviour; and that the data presented and the tasks developed inspire, encourage and enable future research within (and around) these areas.

# References


Abbott, M.W., & Volberg, R.A. (1992). *Frequent gamblers and problem gamblers in New Zealand: Report on phase two of the national survey*. Research Series No. 14. Wellington: New Zealand Department of Internal Affairs.

Albert, M., & Bignami, G. (1968). Effects of frontal medial cortical and caudate lesions on two-way avoidance learning by rats. *Physiology and Behaviour, 3*, 141-147.

Allcock, C.C., & Grace, D.M. (1988). Pathological gamblers are neither impulsive nor sensation-seekers. *Australian and New Zealand Journal of Psychiatry, 22*, 307-311.

American Psychiatric Association. (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington, DC: American Psychiatric Association.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Press.

Aman, C.J., Roberts, R.J., & Pennington. (1998). A neuropsychological examination of the underlying deficit in ADHD: The frontal lobe vs. right parietal lobe theories. *Developmental Psychology, 34*, 956-969.

Avila, C. (2001). Distinguishing BIS-mediated and BAS-mediated disinhibition mechanisms: A comparison of disinhibition models of Gray (1981, 1987) and of Patterson and Newman (1993). *Journal of Personality and Social Psychology, 80*, 311-324.

Avila, C., Molto, J., Segarra, P., & Torrubia, R. (1995). Sensitivity to primary or secondary reinforcers, what is the mechanism underlying passive avoidance deficits in extraverts? *Journal of Research in Personality, 29*, 373-394.

Avila, C., & Parcet, M.A. (2000). The role of Gray's impulsivity in anxiety-mediated differences in resistance to extinction. *European Journal of Personality, 14*, 185-189.

Avila, C., & Parcet, M.A. (2001). Personality and inhibitory deficits in the stop-signal task: The mediating role of Gray's anxiety and impulsivity. *Personality and Individual Differences, 31*, 975-986.

Bachorowski, J.A., & Newman, J.P. (1990). Impulsive motor behavior: Effects of personality and goal salience. *Journal of Personality and Social Psychology, 58*, 512-518.

Band, G.P.H., van der Molen, M.W., Overtoom, C.C.E., & Verbaten, M.N. (2000). On the ability to activate and inhibit speeded responses. *Journal of Experimental Child Psychology, 75*, 263-290.

Barnes, B.L., & Parwani, S. (1987). Personality assessment of compulsive gamblers. *Indian Journal of Clinical Psychology, 14*, 98-99.

Barnes, L.L.B., Harp, D., & Jung, W.S. (2002). Reliability generalization of scores on the Spielberger state-trait anxiety inventory. *Educational and Psychological Measurement, 62*, 603-618.

Bartussek, D., Diedrich, O., Naumann, E., & Collett, W. (1993). Introversion extraversion and event-related potential (ERP): A test of J.A. Gray's theory. *Personality and Individual Differences, 14*, 565-574.

Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S.W., & Nathan, P.E. (2001). Decision-making deficits, linked to a dysfunctional ventro-medial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia, 39*, 376-389.

Bechara, A., Dolan, S., & Hindes, A. (2002). Decision-making and addiction (part II): Myopia for the future or hypersensitivity to reward? *Neuropsychologia, 40*, 1690-1705.

Bechara, A., & Martin, E.M. (2004). Impaired decision making related to working memory deficits in individuals with substance addictions. *Neuropsychology, 18*, 152-162.

Blanco, C., Orensanz-Munoz, L., Blanco-Jerez, C., & Saiz-Ruiz, J. (1996). Pathological gambling and platelet MAO activity: A psychobiological study. *American Journal of Psychiatry, 153*, 119-121.

Blaszczynski, A., McConaghy, N., & Frankova, A. (1990). Boredom Proneness in an impulse control disorder. *Psychological Reports, 67*, 35-42.

Blaszczynski, A., & Nower, L. (2002). A pathways model of problem and pathological gambling. *Addiction, 97*, 487-449.

Blaszczynski, A.P., Steel, Z., & McConaghy, N. (1997). Impulsivity in pathological gambling: The antisocial impulsivist. *Addiction, 92*, 75-87.

Blaszczynski, A., Wilson, A., & McConaghy, N. (1986). Sensation seeking and pathological gambling. *British Journal of Addiction, 81*, 113-117.

Blum, K., Noble, E.P., Sheridan, P.J., Montgomery, A., Ritchie, T., Jagadeeswaran, P., et al. (1990). Allelic association of human dopamine D2 receptor gene in alcoholism. *JAMA, 263*, 2055-2060.

Boddy, J., Carver, A., & Rowley, K. (1986). Effect of positive and negative reinforcement on performance as a function of introversion-extraversion: Some tests of Gray's theory. *Personality and Individual Differences, 7*, 81-88.

Breen, R.B., & Zuckerman, M. (1999). 'Chasing' in gambling behavior: Personality and cognitive determinants. *Personality and Individual Differences, 27*, 1097-1111.

Carlton, P.L., & Manowitz, P. (1994). Factors determining the severity of pathological gambling in males. *Journal of Gambling Studies, 10*, 147-157.

Carrasco, J.L., Saiz-Ruiz, J., Hollander, E., Cesar, J., & Lopez-Ibor, J.J. (1994). Low platelet monoamine oxidase activity in pathological gambling. *Acta Psychiatrica Scandinavica, 90*, 427-431.

Carver, C.S., & White, T. (1994). Behavioural inhibition, behavioural activation, and affective responses to impending reward and punishment: The BIS/BAS scales. *Journal of Personality and Social Psychology, 67*, 319-333.

Castellani, B., & Rugle, L. (1995). A comparison of pathological gamblers to alcoholics and cocaine misusers on impulsivity, sensation seeking, and craving. *International Journal of Addictions, 30*, 275-289.

Cavedini, P., Riboldi, G., Keller, R., D'Annucci, A., & Bellodi, L. (2002). Frontal lobe dysfunction in pathological gambling patients. *Biological Psychiatry*, *51*, 334-341.

Christopherson, K.M., & Weatherly, J.N. (2006). The effect of visual complexity when playing a slot-machine simulation: the role of computer experience, computer anxiety, and optimism. *Computers in Human Behavior*, *22*, 1072-1079.

Comings, D.E., Comings, B.G., Muhleman, D., Dietz, G., Shahbahrami, B., Tast, D., et al. (1991). The dopamine D2 receptor locus as a modifying gene in neuropsychiatric disorders. *JAMA*, *266*, 1793-1800.

Comings, D.E., Rosenthal, R.J., Lesieur, H.R., Rugle, L.J., Muhleman, D., Chiu, C., et al. (1996). A study of the dopamine D2 receptor gene in pathological gambling. *Pharmacogenetics*, *6*, 223-234.

Corr, P.J. (2001). Testing problems in J.A.Gray's personality theory: A commentary on Mathews and Gilliland (1999). *Personality and Individual Differences*, *30*, 333-352.

Corr, P.J. (2002a). J.A.Gray's reinforcement sensitivity theory and frustrative nonreward: A theoretical note on expectancies in reaction to rewarding stimuli. *Personality and Individual Differences*, *32*, 1247-1253.

Corr, P.J. (2002b). J.A.Gray's reinforcement sensitivity theory: Tests of the joint subsystems hypothesis of anxiety and impulsivity. *Personality and Individual Differences*, *33*, 511-532.

Corr, P.J. (2004). Reinforcement sensitivity theory and personality. *Neuroscience and Biobehavioural Reviews*, *28*, 317-332.

Corr, P.J. (2008). *The reinforcement sensitivity theory of personality*. Cambridge: Cambridge University Press.

Corr, P.J. (2009). Anxiety and the Behavioural Inhibition System. In M. Fajkowska & B. Szymura (Eds.) *Anxiety: Genesis-mechanisms-functions*. Warsaw: Scholar Scientific Publisher.

Corr, P.J., Pickering, A.D., & Gray, J.A. (1995). Personality and reinforcement in associative and instrumental learning. *Personality and Individual Differences*, *19*, 47-71.

Corr, P.J., Wilson, G.D., Fotiadou, M., Kumari, V., Gray, N.S., Checkley, S., et al. (1995). Personality and affective modulation of the startle reflex. *Personality and Individual Differences*, *19*, 543-553.

Coventry, K., & Brown, R.I.F. (1993). Sensation seeking, gambling, and gambling addictions. *Addiction*, *88*, 541-554.

Crawford, J.R., & Henry, J.D. (2004). The positive and negative affect schedule (PANAS): Construct validity, measurement properties, and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, *43*, 245-265.

Daugherty, T.K., & Quay, H.C. (1991). Response perseveration and delayed responding in childhood behavioural disorders. *Journal of Child Psychology and Psychiatry*, *32*, 453-461.

Daugherty, T.K., Quay, H.C., & Ramos, L. (1993). Response perseveration, inhibitory control, and central dopaminergic activity in childhood behavior disorders. *Journal of Genetic Psychology*, *154*, 177-188.

DeCaria, C.M., Hollander, E., Grossman, R., Wong, C.M., Mosivich, S.A., & Cherkasky, S. (1996). Diagnosis, neurobiology, and treatment of pathological gamblers. *Journal of Clinical Psychiatry, 57*, 80-84.

De Jong, R., Coles, M.G.H., & Logan, G.D. (1995). Strategies and mechanisms in nonselective and selective inhibitory motor control. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 498-511.

De Jong, R., Coles, M.G.H., Logan, G.D., & Gratton, G. (1990). In search of the point of no return: The control of response processes. *Journal of Experimental Psychology: Human Perception and Performance, 16*, 164-182.

Dickerson, M.G. (1993). Internal and external determinants of persistent gambling: Problems in generalising from one form of gambling to another. *Journal of Gambling Studies, 9*, 225-245.

Dixon, M.R., Marley, J., & Jacobs, E.A. (2003). Delay discounting by pathological gamblers. *Journal of Applied Behavior Analysis, 36*, 449-458.

Dixon, M.R., & Schreiber, J. (2002). Utilizing a computerized video poker simulation for the collection of experimental data on gambling behavior. *The Psychological Record, 52*, 417-428.

Dixon, M.R., & Schreiber, J. (2004). Near-miss effects on response latencies and win estimations of slot machine players. *The Psychological Record, 54*, 335-348.

Elliot, A.J., & Thrash, T.M. (2002). Approach avoidance motivation in personality: Approach and avoidance temperaments and goals. *Journal of Personality and Social Psychology, 82*, 804-818.

Eysenck, H.J. (1967). *The biological basis of personality*. Springfield, IL: Thomas.

Eysenck, H.J. (1990). Biological dimensions of personality. In L.A.Pervin (Ed.) *Handbook of personality: Theory and research*. New York: Guilford.

Eysenck, H.J., & Eysenck, M.W. (1985). *Personality and individual differences: A natural science approach*. New York: Plenum.

Eysenck, H.J., & Eysenck, M.W. (1995). *Mindwatching: Why we behave the way we do*. London: Prion Books.

Eysenck, H.J., & Eysenck, S.B.G. (1975). *The Eysenck personality questionnaire*. London: Hodder and Stoughton.

Eysenck, H.J., & Eysenck, S.B.G. (1978). Impulsiveness and venturesomeness: Their position in a dimensional system of personality description. *Psychological Reports, 43*, 1247-1255.

Eysenck, H.J., & Eysenck, S.B.G. (1991). *The Eysenck personality scales*. London: Hodder and Stoughton.

Eysenck, S.B.G., Eysenck, H.J., & Barrett, P. (1985). A revised version of the psychoticism scale. *Personality and Individual Differences, 6*, 21-29.

Eysenck, S.B.G., & Zuckerman, M. (1978). The relationship between sensation-seeking and Eysenck's dimensions of Personality. *British Journal of Psychology, 69*, 483-487.

Ferris, J., Wynne, H., & Single, E. (1999). *Measuring problem gambling in Canada: Final report—Phase 1.* Inter-Provincial Taskforce on problem gambling. Canada: Canadian Centre of Substance Abuse.

Fillmore, M.T., & Rush, C.R. (2002). Impaired inhibitory control of behavior in chronic cocaine users. *Drug and Alcohol Dependence, 66*, 265-273.

Fillmore, M.T., Rush, C.R., & Hays, L. (2002). Acute effects of oral cocaine on inhibitory control of behavior in humans. *Drug and Alcohol Dependence, 67*, 157-167.

Fillmore, M.T., Rush, C.R., Kelly, H.K., & Hays, L. (2001). Triazolam impairs inhibitory control of behavior in humans. *Experimental and Clinical Psychopharmacology, 7*, 363-371.

Fisher, L., & Blair, R.J.R. (1998). Cognitive impairment and its relationship to psychopathic tendencies in children with emotional and behavioral difficulties. *Journal of Abnormal Child Psychology, 26*, 511-519.

Fonseca, A.C., & Yule, W. (1995). Personality and antisocial behavior in children and adolescents: An inquiry into Eysenck's and Gray's theories. *Journal of Abnormal Psychology, 23*, 767-781.

Fowles, D.C. (1980). The three arousal model: Implications of Gray's two-factor learning theory for heart rate, electrodermal activity, and psychopathy. *Psychophysiology, 17*, 87-104.

Francis, L.J., & Pearson, P.R. (1988). Religiosity and the short scale EPQ-R indices of E, N, and L, compared with the JEPI, JEPQ and EPQ. *Personality and Individual Differences, 9*, 653-657.

Fuentes, D., Tavares, H., Artes, R., & Gorenstein, C. (2006). Self-reported and neuropsychological measures of impulsivity in pathological gambling. *Journal of the International Neuropsychological Society, 12*, 907-912.

*Gambling Act 2005.* London: The Stationary Office.

*Gaming Act 1968.* London: The Stationary Office.

Ghezzi, P., Lyons, C., & Dixon, M.R. (2002). Gambling from a socioeconomic perspective. In W.K.Bickel & R.E.Vuchinich (Eds.) *Reframing health behavior change with behavioral economics.* New York: Erlbaum.

Goodnight, J.A., Bates, J.E., Newman, J.P., Dodge, K.A., & Pettit, G.S. (2006). The interactive influences of friend deviance and reward dominance on the development of externalizing behaviour during middle adolescence. *Journal of Abnormal Child Psychology, 34*, 573-583.

Goudriaan, A.E., Oosterlaan, J., de Beurs, E., & van den Brink, W. (2005). Decision making in pathological gambling: A comparison between pathological gamblers, alcohol dependents, persons with Tourette syndrome and normal controls. *Cognitive Brain Research, 23*, 137-151.

Goudriaan, A.E., Oosterlaan, J., de Beurs, E., & van den Brink, W. (2006). Psychophysiological determinants and concomitants of deficient decision making in pathological gamblers. *Drug and Alcohol Dependence, 84*, 231-239.

Gray, J.A. (1970). The psychophysiological basis of introversion-extraversion. *Behaviour Research and Therapy, 8*, 249-266.

Gray, J.A. (1972a). Learning theory, the conceptual nervous system and personality. In V.D. Nebylitsyn & J.A. Gray (Eds.) *The Biological Bases of Individual Behaviour*. New York: Academic Press.

Gray, J.A. (1972b). The psychophysiological nature of introversion-extraversion: A modification of Eysenck's theory. In V.D. Nebylitsyn & J.A. Gray (Eds.) *The Biological Bases of Individual Behaviour*. New York: Academic Press.

Gray, J.A. (1975). *Elements of a two-process theory of learning*. London: Academic Press.

Gray, J.A. (1981). A critique of Eysenck's theory of personality. In H.J. Eysenck (Ed.) *A Model for Personality*. Berlin: Springer.

Gray, J.A. (1982). *The neuropsychology of anxiety: an enquiry into the functions of the septo-hippocampal system*. Oxford: Oxford University Press.

Gray, J.A. (1987). *The psychology of fear and stress*. Cambridge: Cambridge University Press.

Gray, J.A. (1991). Neural systems, emotion and personality. In J.M. IV. (Ed.) *Neurobiology of Learning, Emotion, and Affect*. New York: Raven Press, Ltd.

Gray, J.A., & McNaughton, N. (2000). *The neuropsychology of anxiety* (2nd ed.). Oxford: Oxford University Press.

Griffiths, M. (2004). Betting your life on it. *British Medical Journal, 329*, 1055-1056.

Gupta, B.S. (1976). Extraversion and reinforcement in verbal and operant conditioning. *British Journal of Psychology, 67*, 47-52.

Gupta, B.S. (1990). Impulsivity/sociability and reinforcement in verbal operant conditioning: A replication. *British Journal of Psychology, 11*, 585-589.

Gupta, B.S., & Nagpal, M. (1978). Impulsivity/sociability and reinforcement in verbal operant conditioning. *British Journal of Psychology, 68*, 203-206.

Gupta, B.S., & Shukla, A.P. (1989). Verbal operant conditioning as a function of extraversion and reinforcement. *British Journal of Psychology, 80*, 39-44.

Halperin, J.M., McKay, K.E., Matier, K., & Sharma, V. (1994). Attention, response inhibition and activity level in children: Developmental neuropsychological perspectives. In M.G. Tramontana & S.R. Hooper (Eds.) *Advances in Child Neuropsychology* (Vol. 2). New York: Springer-Verlag.

Hanes, D.P., Patterson, W.R., & Schall, J.D. (1998). Role of frontal eye fields in countermanding saccades: Visual, movement, and fixation activity. *Journal of Neurophysiology, 79*, 817-834.

Hineline, P.N. (1977). Negative reinforcement and avoidance. In W.K.Honig & J.E.R.Staddon (Eds.) *Handbook of Operant Behavior*. New York: Prentice Hall.

Jackson, C.J., & Francis, L.J. (2004). Are interactions in Gray's reinforcement sensitivity theory proximal or distal in the prediction of religiosity: A test of the joint subsystems hypothesis. *Personality and Individual Differences, 36*, 1197-1209.

Jennings, J.R., van der Molen, M.W., Brock, K., & Somsen, R.J.M. (1992). On the synchrony of stopping motor responses and delaying heartbeats. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 422-436.

Jennings, J.R., van der Molen, M.W., Pelham, W., Brock, K., & Hoza, B. (1997). Inhibition in boys with attention deficit hyperactivity disorder as indexed by heart rate change. *Developmental Psychology, 33*, 308-318.

Jorm, A.F., Christensen, H., Henderson, A.S., Jacomb, P.A., Korten, A.E., & Rogers, B. (1999). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: Factor structure, validity and norms in a large community sample. *Personality and Individual Differences, 26*, 49-58.

Kantorowitz, D.A. (1978). Personality and conditioning of tumescence and detumescence. *Behaviour Research and Therapy, 16*, 117-123.

Kamano, D.K., Martin, L.K., & Powell, B.J. (1966). Avoidance response acquisition and amobarbital dosage levels. *Psychopharmacologia, 8*, 319-323.

Kambouropoulos, N., & Staiger, P.K. (2004). Personality and responses to appetitive and aversive stimuli: The joint influence of behavioural approach and behavioural inhibition systems. *Personality and Individual Differences, 37*, 1153-1165.

Kertzman, S., Lowengrub, K., Aizer, A., Vainder, M., Kotler, M., & Dannon, P.N. (2008). Go-no-go performance in pathological gamblers. *Psychiatry Research, 161*, 1-10.

Kindlon, D., Mezzacappa, E., & Earls, F. (1995). Psychometric properties of impulsivity measures: Temporal stability, validity and factor structure. *Journal of Child Psychology and Psychiatry, 36*, 645-661.

Konorski, J. (1967). *Integrative activity of the brain*. Chicago: University of Chicago Press.

Kooijmans, R., Scheres, A., & Oosterlaan, J. (2000). Response inhibition and measures of psychopathology: A dimensional analysis. *Child Neuropsychology, 6*, 175-184.

Kramer, A.F., Humphrey, D.G., Larish, J.F., Logan, G.D., & Strayer, D.L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention. *Psychology and Aging, 9*, 491-512.

Ladefoged, P., Silverstein, R., & Papcun, G. (1973). Interruptibility of speech. *Journal of the Acoustical Society of America, 54*, 1105-1108.

Lappin, J.S., & Eriksen, C.W. (1966). Use of a delayed signal to stop a visual reaction-time response. *Journal of Experimental Psychology, 72*, 805-811.

Larsen, R.J., & Katelaar, T. (1991). Personality and susceptibility to positive and negative emotional states. *Journal of Personality and Social Psychology, 61*, 132-140.

Lesieur, H.R., & Blume, S.B. (1987). The South Oaks Gambling Screen (SOGS): A new instrument for the identification of pathological gamblers. *American Journal of Psychiatry, 144*, 1184-1188.

Logan, G.D. (1981). Attention, automaticity, and the ability to stop a speeded choice response. In J. Long & A.D. Baddeley (Eds.) *Attention and performance IX*. Hillsdale, NJ: Erlbaum.

Logan, G.D. (1982). On the ability to inhibit complex movements: A stop-signal study of typewriting. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 778-792.

Logan, G.D. (1994). On the ability to inhibit thought and action: A users' guide to the stop-signal paradigm. In D. Dagenbach & T.H. Carr (Eds.) *Inhibitory Processes in Attention, Memory, and Language*. San Diego, CA: Academic Press.

Logan, G.D., & Cowan, W.B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review, 91*, 295-327.

Logan, G.D., Schachar, R.J., & Tannock, R. (1997). Impulsivity and inhibitory control. *Psychological Science, 8*, 60-64.

Loxton, N.J., Nguyen, D., Casey, L., & Dawe, S. (2008). Reward drive, rash impulsivity and punishment sensitivity in problem gamblers. *Personality and Individual Differences, 45*, 167-173.

MacLeod, C.M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*, 163-203.

MacLin, O.H., Dixon, M.R., & Hayes, L.J. (1999). A computerized slot machine simulation to investigate the variables involved in gambling behavior. *Behavior Research Methods, Instruments, & Computers, 31*, 731-734.

Malkin, D., & Syme, G.J. (1986). Personality and problem gambling. *International Journal of the Addictions, 21*, 267-272.

Mangan, G.L. (1978). Factors of conditionability and their relationship to personality types. *Pavlovian Journal of Biological Science, 13*, 226-235.

Matthys, W., van Goozen, S.H.M., Vries, H.D., Cohen-Kettenis, P.T., & van Engeland, H. (1998). The dominance of behavioural activation over behavioural inhibition in conduct disordered boys with or without attention deficit hyperactivity disorder. *Journal of Child Psychology and Psychiatry, 39*, 643-651.

McCord, R.R., & Wakefield, J.A. (1981). Arithmetic achievement as a function of introversion-extraversion and teacher-presented reward and punishment. *Personality and Individual Differences, 2*, 145-152.

McCormick, R.A. (1993). Disinhibition and negative affectivity in substance abusers with and without a gambling problem. *Addictive Behaviours, 18*, 331-336.

McCormick, R.A., Taber, J., Kruedelbach, N., & Russo, A. (1987). Personality profiles of hospitalized pathological gamblers: The California Personality Inventory. *Journal of Clinical Psychology, 43*, 521-527.

McGarry, T., & Franks, I.M. (1997). A horse race between independent processes: Evidence for a phantom point of no return in the preparation of a speeded motor response. *Journal of Experimental Psychology: Human Perception and Performance, 23*, 1533-1542.

McNaughton, N., & Corr, P.J. (2004). A two-dimensional neuropsychology of defense: Fear/anxiety and defensive distance. *Neuroscience & Biobehavioural Reviews, 28*, 285-305.

McNaughton, N., & Corr, P.J. (2008). The neuropsychology of fear and anxiety: A foundation for Reinforcement Sensitivity Theory. In P.J. Corr (Ed.) *The Reinforcement Sensitivity Theory of Personality*. Cambridge: Cambridge University Press.

McNaughton, N., & Corr, P.J. (2009). Central theories of motivation and emotion. In G.G. Berntson & J.T. Cacioppo (Eds.) *Handbook of neuroscience for the behavioural sciences*. London: Wiley.

Michael, J. (1993). Establishing operations. *The Behavior Analyst, 16*, 2-24.

Mischel, W. (1980). Personality and cognition: Something borrowed, something new? In N. Cantor & J. Kihlstrom (Eds.) *Personality, Cognition, and Social Interaction*. Hillsdale, NJ: Erlbaum.

Mischel, W., Shoda, Y., & Smith, R.E. (2004). *Introduction to personality: Toward an integration* (7th ed.) pp. 3-4. New York: Wiley.

Mulvihill, L.E., Skilling, T.A., & Vogel-Sprott, M. (1997). Alcohol and the ability to inhibit behavior in men and women. *Journal of Studies on Alcohol, 58*, 600-605.

Nagpal, M., & Gupta, B.S. (1979). Personality, reinforcement and verbal operant conditioning. *British Journal of Psychology, 70*, 471-476.

Newman, J.P., & Kosson, D.S. (1986). Passive avoidance learning in psychopathic and nonpsychopathic offenders. *Journal of Abnormal Psychology, 95*, 252-256.

Newman, J.P., & Lorenz, A. (2001). Response modulation and emotion processing: Implications for psychopathy and other dysregulatory psychopathology. In R.J. Davidson, K. Scherer, & H.H. Goldsmith (Eds.) *Handbook of Affective Sciences*. Oxford: Oxford University Press.

Newman, J.P., Patterson, C.M., Howland, E.W., & Nichols, S.L. (1990). Passive avoidance in psychopaths: The effects of reward. *Personality and Individual Differences, 11*, 1101-1114.

Newman, J.P., Patterson, C.M., & Kosson, D.S. (1987). Response perseveration in psychopaths. *Journal of Abnormal Psychology, 96*, 145-148.

Newman, J.P., & Schmitt, W.A. (1998). Passive avoidance in psychopathic offenders: A replication and extension. *Journal of Abnormal Psychology, 107*, 527-532.

Newman, J.P., & Wallace, J.F. (1993). Diverse pathways to deficient self-regulation: Implications for disinhibitory psychopathology in children. *Clinical Psychology Review, 13*, 699-720.

Newman, J.P., Wallace, J.F., Schmitt, W.A., & Arnett, P.A. (1997). Behavioral inhibition system functioning in anxious, impulsive and psychopathic individuals. *Personality and Individual Differences, 23*, 583-592.

Noble, E.P. (2003). D2 dopamine receptor gene in psychiatric and neurologic disorders and its phenotypes. *American Journal of Medical Genetics, 116*, 103-125.

Nordin, C., & Eklundh, T. (1999). Altered CSF 5-HIAA disposition in pathologic male gamblers. *CNS Spectrums, 4*, 25-33.

O'Brien, B.S., & Frick, P.J. (1996). Reward dominance: associations with anxiety, conduct problems, and psychopathy in children. *Journal of Abnormal Child Psychology, 24*, 223-240.

O'Connor, R.M., Colder, C.R., & Hawk, L.W.Jr. (2004). Confirmatory factor analysis of the sensitivity to punishment and sensitivity to reward questionnaire. *Personality and Individual Differences, 37*, 985-1002.

Oei, T.P.S., Cavallo, G., & Evans, L. (1987). Utility of fear survey schedule with Australian samples of anxiety disorder patients. *Journal of Behaviour Therapy and Experimental Psychiatry, 18*, 329-336.

Oosterlaan, J., Logan, G.D., & Sergeant, J.A. (1998). Response inhibition in AD/HD, CD, comorbid AD/HD + CD, anxious and control children: A meta-analysis of studies with the stop-task. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 39*, 411-425.

Oosterlaan, J., & Sergeant, J. (1996). Inhibition in ADHD, anxious and aggressive children: A biologically based model of child psychology. *Journal of Abnormal Child Psychology, 24*, 19-36.

Oosterlaan, J., & Sergeant, J.A. (1997). Effects of reward and response cost on response inhibition in AD/HD, disruptive, anxious, and normal children. *Journal of Abnormal Child Psychology, 26*, 161-174.

Oosterlaan, J., & Sergeant, J.A. (1998). Response inhibition and response re-engagement in attention deficit/hyperactivity disorder, disruptive, anxious, and normal children. *Behavioural Brain Research, 94*, 33-43.

Overtoom, C.C.E., Kenemans, J.L., Verbaten, M.N., Kemmer, C., van der Molen, M.W., van Engeland, H., et al. (2002). Inhibition in children with attention-deficit/hyperactivity disorder: A psychophysiological study of the stop task. *Biological Psychiatry, 51*, 668-676.

Paisey, T.J.H., & Mangan, G.L. (1988). Personality and conditioning with appetitive and aversive stimuli. *Personality and Individual Differences, 9*, 69-78.

Patterson, C.M., Kosson, D.S., & Newman, J.P. (1987). Reaction to punishment, reflectivity, and passive avoidance learning in extraverts. *Journal of Personality and Social Psychology, 52*, 565-567.

Patterson, C.M., & Newman, J.P. (1993). Reflectivity and learning from aversive events: Toward a psychological mechanism for Syndromes of Disinhibition. *Psychological Review, 100*, 716-736.

Perkins, A.M., Kemp, S.E., & Corr, P.J. (2007). Fear and anxiety as separable emotions: An investigation of the revised reinforcement sensitivity theory of personality. *Emotion, 7*, 252-261.

Pervin, L.A. (1996). *The science of personality*. New York: Wiley.

Petry, N.M., & Roll, J.M. (2001). A behavioral approach to understanding and treating pathological gambling. *Seminars in Clinical Neuropsychology, 6*, 177-183.

Pickering, A.D., Corr, P.J. & Gray, J.A. (1999). Interactions and reinforcement sensitivity theory: A theoretical analysis of Rusting and Larsen (1997). *Personality and Individual Differences, 26*, 357-365.

Pickering, A.D., Corr, P.J., Powell, J.H., Kumari, V., Thornton, J.C., & Gray, J.A. (1997). Individual differences in reactions to reinforcing stimuli are neither black nor white: To what extent are they gray? In H. Nyborg (Ed.) *The Scientific Study of Human Nature: Tribute to Hans J. Eysenck at Eighty*. London: Elsevier Sciences.

Ponce, G., Jimenez-Arriero, M.A., Rubio, G., Hoenicka, J., Ampuero, I., Ramos, J.A., et al. (2003). The A1 allele of the *DRD2* gene (*TaqI* A polymorphisms) is associated with antisocial personality in a sample of alcohol-dependent patients. *European Psychiatry, 18*, 356-360.

Posner, M.I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bouwhuis (Eds.) *Attention and Performance X*. Hillsdale, NJ: Erlbaum.

Potenza, M.N., Steinberg, M.A., Skudlarski, P., Fulbright, R.K., Lacadie, C.M., Wilber, M.K., et al. (2003). Gambling urges in pathological gambling: A functional magnetic resonance imaging study. *Archives of General Psychiatry, 60*, 828-836.

Quay, H.C. (1988). The behavioural reward and inhibition system in childhood behavioural disorders. In L.M. Bloomingdale (Ed.) *Attention Deficit Disorder*. Oxford: Pergamon Press.

Quay, H.C. (1993). The psychobiology of undersocialized aggressive conduct disorder: A theoretical perspective. *Development and Psychopathology, 5*, 165-180.

Quay, H.C. (1997). Inhibition and attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology, 25*, 7-13.

Raylu, N., & Oei, T.P.S. (2002). Pathological gambling a comprehensive review. *Clinical Psychology Review, 22*, 1009-1061.

Ridderinkhof, K.R., Band, G.P.H., & Logan, G.D. (1999). A study of adaptive behavior: Effects of age and irrelevant information on the ability to inhibit one's actions. *Acta Psychologica, 101*, 315-337.

Rodriguez-Fornells, A., Lorenzo-Seva, U., & Andres-Pueyo, A. (2002). Are high-impulsive and high risk-taking people more motor disinhibited in the presence of incentive? *Personality and Individual Differences, 32*, 661-683.

Rodriguez-Jimenez, R., Avila, C., Jimenez-Arriero, M.A., Ponce, G., Monasor, R., Jimenez, M., et al. (2006a). Impulsivity and sustained attention in pathological gamblers: Influence of childhood ADHD history. *Journal of Gambling Studies, 22*, 451-461.

Rodriguez-Jimenez, R., Avila, C., Ponce, G., Ibanez, M.I., Rubio, G., Jimenez-Arriero, M.A., et al. (2006b). The TaqIA polymorphism linked to the DRD2 gene is related to lower attention and less inhibitory control in alcoholic patients. *European Psychiatry, 21*, 66-69.

Ross, S.R., Millis, S.R., Bonebright, T.L., & Bailley, S.E. (2002). Confirmatory factor analysis of the behavioural inhibition and activation scales. *Personality and Individual Differences, 33*, 861-865.

Roy, A., Custer, R., Lorenz, V., & Linnoila, M. (1989). Personality factors and pathological gambling. *Acta Psychiatrica Scandinavica, 80*, 37-39.

Rubia, K., Oosterlaan, J., Sergeant, J.A., Brandeis, D., & Leeuwen, T.V. (1998). Inhibitory dysfunction in hyperactive boys. *Behavioural Brain Research, 94*, 25-32.

Schachar, R.J., & Logan, G.D. (1990). Impulsivity and inhibitory control in normal development and childhood psychopathology. *Developmental Psychology, 26*, 710-720.

Schachar, R., & Tannock, R. (1995). Test of four hypotheses for the comorbidity of attention-deficit hyperactivity disorder and conduct disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 34*, 639-648.

Schachar, R., Tannock, R., Marriott, M., & Logan, G. (1995). Deficient inhibitory control in attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology, 23*, 411-437.

Schreiber, J., & Dixon, M.R. (2001). Temporal characteristics of behavior on random-ratio schedules observed during slot machine play. *Psychological Reports, 89*, 67-72.

Séguin, J.R., Arseneault, L., Boulerice, B., Harden, P., & Tremblay, R.E. (2002). Response perseveration in adolescent boys with stable and unstable histories of physical aggression: The role of underlying processes. *Journal of Child Psychology and Psychiatry, 43*, 481-494.

Seunath, O.M. (1975). Personality, reinforcement and learning. *Perceptual and Motor Skills, 41*, 459-463.

Shapiro, S.K., Quay, H.C., Hogan, A.E., & Schwartz, K.P. (1988). Response perseveration and delayed responding in undersocialized aggressive conduct disorder. *Journal of Abnormal Psychology, 97*, 371-373.

Siegel, R. (1978). Probability of punishment and suppression of behaviour in psychopathic and nonpsychopathic offenders. *Journal of Abnormal Psychology, 87*, 514-522.

Spielberger, C.D., Gorsuch, R.L., & Lushene, R.E. (1970). *Manual for the state-trait anxiety inventory*. Palo Alto, CA: Consulting Psychologists Press.

Spielberger, C.D., Gorsuch, R.L., Lushene, R.E., Vagg, P.R., & Jacobs, G.A. (1983). *Manual for the state-trait anxiety inventory: STAI (form Y2)*. Palo Alto, CA: Consulting Psychologists Press.

Sproston, K., Erens, B., & Orford, J. (2000). *Gambling behaviour in Britain: Results from the British gambling prevalence survey*. London: National Centre for Social Research.

Stinchfield, R. (2002). Reliability, validity, and classification accuracy of the South Oaks Gambling Screen (SOGS). *Addictive Behaviors, 27*, 1-19.

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics*. Boston, MA: Allyn and Bacon.

Tannock, R., Schachar, R.J., Carr, R.P., Chajczyk, D., & Logan, G.D. (1989). Effects of methylphenidate on inhibitory control in hyperactive children. *Journal of Abnormal Child Psychology, 17*, 473-491.

Tannock, R., Schachar, R.J., & Logan, G.D. (1995). Methylphenidate and cognitive flexibility: Dissociated dose effects in hyperactive children. *Journal of Abnormal Child Psychology, 23*, 235-267.

Thornquist, M.H., & Zuckerman, M. (1995). Psychopathy, passive avoidance learning and basic dimensions of personality. *Personality and Individual Differences, 19*, 525-534.

Tipper, S.P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology, 37A*, 571-590.

Torrubia, R., Avila, C., Molto, J., & Caseras, X. (2001). The sensitivity to punishment and sensitivity to reward questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences, 31*, 837-862.

Torrubia, R., Avila, C., Molto, J., & Grande, I. (1995). Testing for stress and happiness: The role of the behavioural inhibition system. In C.D. Spielberg, I.G. Sarason, J. Brebner, E. Greenglass, P. Langani, & A.M. O'Rourke (Eds.) *In Stress and Emotion: Anxiety, Anger, and Curiosity* (Vol. 15). Washington, DC: Taylor and Francis.

Van den Wildenberg, W.P.M., van Boxtel, G.J.M., & van der Molen, M.W. (2003). The duration of response inhibition in the stop-signal paradigm varies with response force. *Acta Psychologica, 114*, 115-129.

Van Boxtel, G.J.M., van der Molen, M.W., Jennings, J.R., & Brunia, C.H.M. (2001). A psychophysiological analysis of inhibitory motor control in the stop-signal paradigm. *Biological Psychology, 58*, 229-262.

Van Goozen, S.H.M., Cohen-Kettenis, P.T., Snoek, H., Matthys, W., Swaab-Barneveld, H., & van Engeland, H. (2004). Executive functioning in children: A comparison of hospitalised ODD and ODD/ADHD children and normal controls. *Journal of Child Psychology & Psychiatry, 45*, 284-292.

Vitaro, F., Arseneault, L., & Tremblay, R.E. (1999). Impulsivity predicts problem gambling in low SES adolescent males. *Addiction, 94*, 565-575.

Walker, M.B., & Dickerson, M.G. (1996). The prevalence of problem and pathological gambling: A critical analysis. *Journal of Gambling Studies, 12*, 233-249.

Wallace, J.F., & Newman, J.P. (1990). Differential effects of reward and punishment cues on response speed in anxious and impulsive individuals. *Personality and Individual Differences, 11*, 999-1010.

Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 47*, 1063-1070.

Weatherly, J.N., & Brandt, A.E. (2004). Participants' sensitivity to percentage payback and credit value when playing a slot-machine simulation. *Behavior and Social Issues, 13*, 33-50.

Weatherly, J.N., McDougal, C.L., & Gillis, A.A. (2006). A bird in hand: Discouraging gambling on a slot machine simulation. *The Journal of Psychology, 140*, 347-361.

Weatherly, J.N., Sauter, J.M., & King, B.M. (2004). The "big win" and resistance to extinction when gambling. *The Journal of Psychology, 138*, 495-504.

Williams, B.R., Ponesse, J.S., Schachar, R.J., Logan, G.D., & Tannock, R. (1999). Development of inhibitory control across the life span. *Developmental Psychology, 35*, 205-213.

Wolpe, J., & Lang, P.J. (1977). *Manual for the fear survey schedule*. San Diego, CA: Educational and Industrial Testing Service.

Zuckerman, M. (1979). *Sensation seeking: Beyond the optimal level of arousal*. Hillsdale, NJ: Erlbaum.

Zuckerman, M. (1994). *Behavioural expressions and biosocial bases of sensation seeking*. New York: Cambridge University Press.

Zuckerman, M., Kuhlman, M., Joireman, J., Teta, P., & Kraft, M. (1993). A comparison of three structural models for personality: The big three, the big five, and the alternative five. *Journal of Personality and Social Psychology, 65*, 757-768.

# Appendices

APPENDIX A: Written Baseline stop-signal task instructions (given to participants in chapters 3, 4, 6, & 7).

APPENDIX B: Written Punishment stop-signal task instructions (given to participants in chapter 3, Experiment 1).

APPENDIX C: Written Reward stop-signal task instructions (given to participants in chapter 3, Experiment 1).

APPENDIX D: Written Conflict stop-signal task instructions (given to participants in chapter 3, Experiment 1).

APPENDIX E: Modified written Punishment stop-signal task instructions (given to participants in: chapter 3, Experiments 2 & 3; chapters 4, 6, & 7).

APPENDIX F: Modified written Reward stop-signal task instructions (given to participants in: chapter 3, Experiments 2 & 3; chapters 4, 6, & 7).

APPENDIX G: Modified written Conflict stop-signal task instructions (given to participants in: chapter 3, Experiments 2 & 3; chapters 4, 6, & 7).

APPENDIX H: Written Q-task instructions (given to participants in chapters 4 & 6).

APPENDIX I: Written card perseveration (CP) task instructions (for the first version administered; 'Standard' or 'Pause', depending on group; given to participants in chapters 5 & 6).

APPENDIX J: Written card perseveration (CP) task instructions (for the second version administered; 'Standard' or 'Pause', depending on group; given to participants in chapters 5 & 6).

APPENDIX K: Written instructions for slot machine simulation with high percentage payback rate (given to participants in chapters 5 & 6).

APPENDIX L: Written instructions for slot machine simulation with low percentage payback rate (given to participants in chapters 5 & 6).

APPENDIX M: Visual analogue scales used to assess levels of reinforcement expectancies in relation to the Baseline task, the Punishment task, and the Conflict task (given to participants in chapter 7).

# Appendix A

## B-Task Instructions

This task involves making speeded responses to letters that appear in the centre of a computer screen.

You are required to press the '1' key on the keyboard number pad whenever the letter is an 'A' or a 'B'. Whenever the letter is a 'C' or a 'D' you should press the '2' key. You should respond with index and middle fingers of your preferred hand as quickly as possible without making errors.

However, you should inhibit your response (not press any key) to these letters if a green circle appears above the letter shortly after the letter appears. This green circle is a stop-signal and will occur at different delays, so sometimes you will be able to stop yourself pressing a key and sometimes you will not.

You should try to inhibit your response to the letters when this stop-signal appears, but this response inhibition is hard to make, so don't worry if you are not able to do it.

It is important that you do not wait for the stop-signal. You should not let the stop-task interfere with your performance on the go-task. Respond as quickly as possible to the letters using the appropriate keys, only inhibiting your response to the stop-signal when possible.

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix B

## P-Task Instructions

This task requires the same from you as the first task except for one important difference: your performance in this task will be monitored and compared with the average individual.

Points will be deducted for every error you make whilst performing this task. The more points you lose, the lower your overall score and performance will be for this task. Points will be deducted for responding with the wrong key or failing to respond to the go-task (without a stop-signal). Points will also be deducted for failing to inhibit your response when a stop-signal appears.

If you respond with the wrong key or fail to respond to non-stop stimuli (letters without the green circle) you will lose 5 points. If you respond with the correct key to non-stop stimuli you will not lose any points.

In the stop-signal trials (when the green circle appears), if you do not inhibit your response, you will lose 5 points. If you refrain from responding in the stop-signal trials you will not lose any points.

After each trial, if you have lost 5 points you will briefly see '-5' displayed in the centre of the computer screen before the next trial begins. If you have not lost any points in the trial the computer screen will remain blank until the next trial begins.

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix C

## R-Task Instructions

This task requires the same from you as the first task except for one important difference: your performance in this task will be monitored and compared with the average individual.

If you respond very fast to the go-task (without a stop-signal) you will be awarded points. The more points you are awarded, the higher your overall score and performance will be for this task.

If your reaction time to non-stop stimuli (letters without the green circle) is faster than your mean reaction time (obtained in the first task) you will earn 5 points. If you respond with the wrong key, fail to respond, or respond slower than your mean reaction time to non-stop stimuli you will not earn any points.

After each trial, if you have earned 5 points you will briefly see '5' displayed in the centre of the computer screen before the next trial begins. If you have not earned any points in the trial the computer screen will remain blank until the next trial begins.

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.

# Appendix D

## C-Task Instructions

This task requires the same from you as the first task except for one important difference: your performance in this task will be monitored and compared with the average individual.

Points will be awarded or deducted depending on how you perform in the trials of this task. The more points you are awarded, the higher your overall score and performance will be for this task. The more points you get deducted, the lower your overall score and performance will be for this task.

If your reaction time to non-stop stimuli (letters without the green circle) is faster than your mean reaction time (obtained in the first task) you will earn 5 points. However, if your reaction time is slower than your mean reaction time you will be awarded 0 points. If the response is completed with the wrong key or you fail to respond, you will lose 5 points.

In the stop-signal trials (when the green circle appears), if you refrain from responding you will receive 0 points. However, if you do not inhibit your response, you will lose 5 points.

After each trial you will briefly see the number of points earned ('5', '0' or '-5') displayed in the centre of the computer screen before the next trial begins.

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix E

## P-Task Instructions

This task requires the same from you as the first task except for one important difference: **your performance in this task will be monitored and compared with the average individual.**

Points will be deducted for every error you make whilst performing this task. The more points you lose, the lower your overall score and performance will be. Points will be deducted for responding with the wrong key or failing to respond to the go-task (without a stop-signal). Points will also be deducted for failing to inhibit your response when a stop-signal appears.

After each trial, if you have lost points the computer screen will briefly turn red and display the text "POOR! You lose 10 points!" but if you have not lost any points the computer screen will remain blank until the next trial begins.

Remember, your performance in this task will be compared with the average individual so get the best score possible!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.

# Appendix F

## R-Task Instructions

This task requires the same from you as the first task except for one important difference: **your performance in this task will be monitored and compared with the average individual.**

Points will be awarded for responding very fast to the go-task (without a stop-signal). The more points you win, the higher your overall score and performance will be.

After each trial, if you have won points the computer screen will briefly turn blue and display the text "GOOD! You win 10 points!" but if you have not won any points the computer screen will remain blank until the next trial begins.

Remember, your performance in this task will be compared with the average individual so get the best score possible!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix G

## C-Task Instructions

This task requires the same from you as the first task except for one important difference: **your performance in this task will be monitored and compared with the average individual.**

Points will be awarded or deducted depending on how you perform this task. The more points you win, the higher your overall score and performance will be. The more points you lose, the lower your overall score and performance will be.

Points will be awarded for responding very fast to the go-task (without a stop-signal). Points will be deducted for responding with the wrong key or failing to respond to the go-task (without a stop-signal). Points will also be deducted for failing to inhibit your response when a stop-signal appears.

After each trial, if you have won points the computer screen will briefly turn blue and display the text "GOOD! You win 10 points!", if you have lost points the computer screen will briefly turn red and display the text "POOR! You lose 10 points!", or if you have not won or lost any points the computer screen will remain blank until the next trial begins.

Remember, your performance in this task will be compared with the average individual so get the best score possible!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix H

The following task involves responding to a series of letters and/or numbers that appear on the computer screen.

Read the onscreen instructions and only begin the task when you have fully understood them.

Approximately half-way through the task you will be presented with another set of onscreen instructions.

The task will end with the text “Thank you for your participation” appearing in the upper left-hand corner of the computer screen; when you see this message, please alert the experimenter.

# Appendix I

This task involves playing a simple gambling-type card game presented on a computer.

You will have the opportunity to both win and lose "cash" by choosing to draw cards from a face-down deck on the computer screen. This is not a normal 52-card deck so the same card(s) may appear more than once. Cards may be drawn one-at-a-time by clicking on the 'Draw' button. If you choose to draw a card and it happens to be a face card (i.e., Jack, Queen, King, Ace) then you will win $10. If the card you choose to draw happens to be a number card (i.e., 2-10) then you will lose $10. You will begin the game with $100 and you should try to finish the game with as much cash as possible. You can finish the game whenever you like by clicking on the 'Exit' button. Alternatively, the game finishes automatically if you lose all of your cash.

Although the cash you are playing for is not real money, the amount of cash you finish the game with will be compared to the average individual's winnings on this game so try to finish with as much cash as possible!!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.

# Appendix J

You are now going to play a similar gambling-type card game to the one you have just played. The rules of this game are the same as the first card game.

You will again begin the game with $100 and you should try to finish the game with as much cash as possible. Again it is not a normal 52-card deck so the same card(s) may appear more than once. You can finish the game whenever you like by clicking on the 'Exit' button. Alternatively, the game finishes automatically if you lose all of your cash.

Again, although the cash you are playing for is not real money, the amount of cash you finish the game with will be compared to the average individual's winnings on this game so try to finish with as much cash as possible!!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.

# Appendix K

The following computerised slot machine is designed to mimic those that you would find in an actual casino. You will be staked with 100 credits to begin with and your goal is to end with as many credits as possible.

To play the slot machine, click the mouse on either the ‘BET ONE’ button or the ‘BET Max’ button depending on whether you wish to bet 1 credit or 3 credits, then click on the ‘SPIN REELS’ button.

If three of the exact same symbols roll in on the middle row of the machine then you will win 2x the credits you bet. If you clicked on the ‘BET ONE’ button before spinning the reels you would win 2 credits and if you clicked on the ‘BET Max’ button you would win 6 credits.

However, if various different symbols roll in on the middle row of the machine then you will lose the number of credits you bet. If you clicked on the ‘BET ONE’ button before spinning the reels you would lose 1 credit and if you clicked on the ‘BET Max’ button you would lose 3 credits.

Keep playing the slot machine until you are prompted to click on the ‘CASH OUT’ button. The amount of credits you cash out at the end of play will be compared to the average individual so try to end with as many credits as possible.

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.



*Task available on request*

# Appendix L

You are going to play the slot machine now for a second time. You will again be staked with 100 credits to begin with and again your goal is to end with as many credits as possible. Remember that the amount of credits you cash out at the end of play will be compared to the average individual's winnings on this slot machine so try to end with as many credits as possible!!

When you have read and fully understood these instructions please ask the experimenter if you have any further questions.

# Appendix M

Scales used in conjunction with the Baseline stop-signal task:

How rewarding do you expect the B-Task to be?

| | | |
|---|---|---|
| Not at all rewarding | ____________________ | Very rewarding |

How rewarding did you find the B-Task?

| | | |
|---|---|---|
| Not at all rewarding | ____________________ | Very rewarding |

Scales used in conjunction with the Punishment stop-signal task:

How rewarding do you expect the P-Task to be?

| | | |
|---|---|---|
| Not at all rewarding | ____________________ | Very rewarding |

How rewarding did you find the P-Task?

| | | |
|---|---|---|
| Not at all rewarding | ____________________ | Very rewarding |

Scales used in conjunction with the Conflict stop-signal task:

How rewarding do you expect the C-Task to be?

| | | |
|---|---|---|
| Not at all rewarding | ______________________________ | Very rewarding |

How rewarding did you find the C-Task?

| | | |
|---|---|---|
| Not at all rewarding | ______________________________ | Very rewarding |

*Note.* Each individual scale in this Appendix was administered on a separate A4 sized sheet of paper. Participants were verbally instructed to answer the question by putting a vertical line through the scale at the point at which most accurately reflected their feelings.